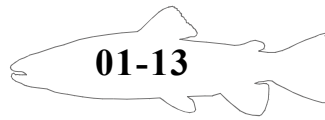
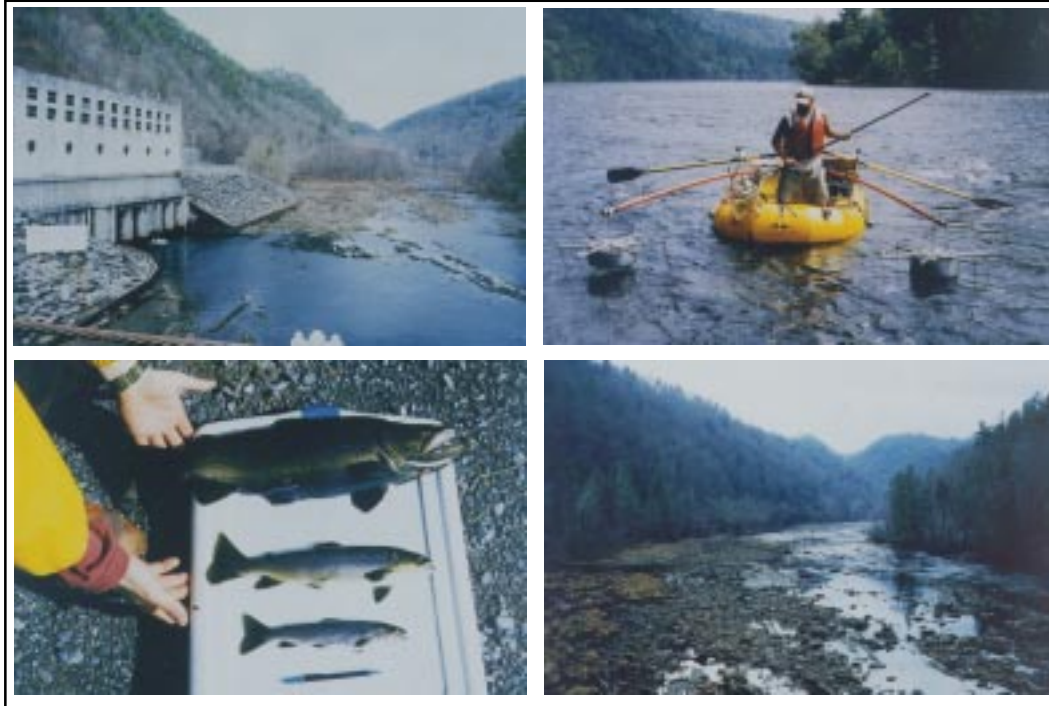


# FISHERIES REPORT



## **An Investigation of the Trout Fishery in the Hiwassee River**



A Final Report Presented  
to the Tennessee Wildlife Resources Agency  
by

Michael P. Luisi, M.S.  
Phillip W. Bettoli, Ph.D.

Tennessee Cooperative Fisheries Research Unit  
U.S. Geological Survey, Biological Resources Division  
Tennessee Technological University  
Cookeville, TN 38505

**Tennessee Wildlife**



**Resources Agency**

June 2001

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## *Executive Summary*

1. The Hiwassee River below Apalachia Powerhouse is managed by the Tennessee Wildlife Resources Agency as a put-and-take trout fishery and is annually stocked with about 100,000 catchable (> 200 mm total length, TL) rainbow trout and 17,500 catchable brown trout. Detailed information pertaining to the fate of these stocked trout was not available when this study was initiated in 1999.

2. Growth, survival, and harvest rates were estimated by microtagging four cohorts of rainbow trout Oncorhynchus mykiss ( $n \geq 11,000$  each) and all of the brown trout Salmo trutta ( $n = 17,870$ ) stocked in 1999. Electrofishing samples were collected at fixed transects approximately monthly between February and December 1999 using an electrofishing raft and a jet-drive electrofishing boat. Population estimates were derived from change-in-ratio experiments conducted in January 1999 and 2000. A concurrent roving creel survey was conducted to estimate fishing pressure and harvest rates.

3. Nearly all rainbow trout grew slowly, if at all. Brown trout exhibited some growth in late spring and early summer (0.28 mm/day), but growth ceased after 100 days. Some of the rainbow trout stocked in July 1999 moved up to the reach immediately below the powerhouse and preyed heavily on entrained clupeids Alosa spp., which resulted in rapid growth rates of 8 mm and 54 g/month. With those exceptions, the condition of all stocked trout declined significantly over the course of our study.

5. Brown trout exhibited the highest 200-day survival rate (13%), but survival was poor for all cohorts. The harvest rate for rainbow trout stocked in January was high (54%); however, return rates for brown trout and the other three rainbow trout cohorts were low (4 – 22%).

6. Fishing pressure between 30 January and 20 November 1999 (42 weeks) totaled 73,842 hours and represented 20,761 trips. Given the large size of the tailwater (307 hectares at baseflow between the powerhouse and the new Patty Bridge), fishing pressure only amounted to 5.7 hours/hectare/week. Fishing pressure was light below Reliance, and almost non-existent between the Highway 411 bridge in Benton and the new Patty Bridge.

7. Fishing pressure peaked at more than 5,000 hours per two-week period between late March and mid-June, which coincided with baseflows resulting from drought conditions. Anglers harvested 1.15 fish per trip and most (72%) anglers reported catching at least one trout per trip. Twenty-two percent of the anglers were out-of-state residents; most (71%) of the Tennessee residents resided in Bradley, Hamilton, and McMinn counties.

## *Executive Summary - continued*

8. Water temperatures in the Hiwassee River commonly exceeded 21 C during late spring and summer 1999, and poor survival rates of stocked trout could have been due, in part, to some initial stocking mortality. In a laboratory experiment, rainbow trout acclimated to 10C (simulating the temperatures in hatchery hauling tanks) experienced partial equilibrium loss when subjected to 24 C and full loss of equilibrium at 27 C. No acute effects were noted for fish tested at 18 or 21 C.

9. Few trout were present in the Hiwassee River in January 1999 (61/ha) or January 2000 (22/ha); the corresponding standing crops (20 and 13 kg/ha, respectively) were the lowest observed to date in any tailwater managed for trout in Tennessee. The low biomass of holdover trout, poor survival, and slow growth were attributed to the unproductive nature of the Hiwassee River ( $\leq 12\text{mg/L CaCO}_3$ ) and the low flows and high temperatures (20 – 25 C) experienced during 1999, a drought year.

10. Few trout of quality-size (i.e.,  $\geq 356$  mm; 14 inches) were present anywhere in the Hiwassee River, including the 6-km Quality Zone (QZ) reach. Growth was too slow and few trout survived from one year to the next to reach larger sizes in any reach of the river. The clerk observed 84 rainbow trout and 20 brown trout that were harvested in the QZ, only one of which was a legal fish (i.e.,  $> 356$  mm TL).

11. Rainbow trout and brown trout struggled to survive in the Hiwassee River during the drought of 1999. Although low flows and high temperatures undoubtedly contributed to the poor growth and survival of trout during our study, high water temperatures are a chronic problem on the river, which the drought merely exacerbated.

## **ACKNOWLEDGEMENTS**

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Previous drafts of this document were reviewed and edited by Drs. Frank Bulow and Jack Gordon, Tennessee Technological University, and Frank Fiss, Tennessee Wildlife Resources Agency.

## **FORWARD**

This final report is based on a thesis prepared by the first author in partial fulfillment of the requirements for the Master of Science degree at Tennessee technological University.

## TABLE OF CONTENTS

|  |    |
|--|----|
| INTRODUCTION .....                     | 5  |
| STUDY AREA .....                       | 6  |
| METHODS .....                          | 7  |
| Trout Marking .....                    | 7  |
| Trout Stocking and Sampling .....      | 7  |
| Population Estimates.....              | 8  |
| Habitat Mapping and Water Quality..... | 9  |
| Temperature Tolerance .....            | 10 |
| Creel Survey.....                      | 10 |
| Data Analysis.....                     | 11 |
| RESULTS .....                          | 12 |
| Survival.....                          | 12 |
| Growth.....                            | 12 |
| Standing Crop Estimates.....           | 13 |
| Creel Survey and Return Rates.....     | 13 |
| Habitat Survey .....                   | 15 |
| Temperature Tolerance .....            | 15 |
| DISCUSSION .....                       | 16 |
| Survival and Harvest.....              | 16 |
| Growth and Condition.....              | 17 |
| Habitat and Water Quality.....         | 19 |
| Standing Crops.....                    | 19 |
| CONCLUSIONS.....                       | 21 |
| REFERENCES.....                        | 22 |
| TABLES .....                           | 28 |
| FIGURES .....                          | 37 |
| APPENDIX.....                          | 58 |

## INTRODUCTION

Beginning with the construction of Norris Dam by the Tennessee Valley Authority (TVA) in 1937 on the Clinch River, hypolimnetic discharges have been managed by fisheries managers in Tennessee and elsewhere to provide angling opportunities where coldwater habitat never existed (Axon 1974). Across the country, put-and-take trout fishing became an integral part of the recreational opportunities available in each state. In an effort to utilize the habitat provided by hypolimnetic discharges, tailwaters in the Southeastern U.S. are regularly stocked with rainbow trout Oncorhynchus mykiss and brown trout Salmo trutta.

The fluctuating discharge that occurs below a typical hydroelectric facility is the result of a demand for hydroelectric power, flood control and recreational releases (Parsons 1957; Cushman 1985). Peaking hydroelectric discharges subsequently have ecological effects in downstream reaches that influence trout growth (Weisburg and Burton 1993) and survival (Grizzle 1981).

Fluctuations in flow create an unstable aquatic environment (Radford and Hartland-Row 1971), resulting in a reduction of a stream's carrying capacity (Neel 1963) and poor fish community structure (Bain et al. 1988). This instability, which is the result of changes in water velocity and depth, creates an unsuitable environment for many benthic macroinvertebrate species (Odenkirk and Estes 1991). Benthic taxa can become lost in the drift or dewatered during periods of rapid changes in water levels and velocity (Brusven 1984; Layzer et al. 1989).

The scouring effect caused by fluctuating hypolimnetic releases can reduce a river's productivity. The rainbow trout fishery in the upper Kennebec River, Maine, suffered as a result of extreme flow alterations, which caused the scouring of the streambed and a reduction of the benthic invertebrate populations (Trotzky and Gregory 1974). Studies by Radford and Hartland-Rowe (1971) on the Kananaskis River, Alberta, Blanz et al. (1969) on the White River, Arkansas, and McGary and Harp (1975) on the Little Red River, Arkansas, all noted that benthic communities are depauperate on regulated streams when compared to natural systems. Trout rely heavily on benthic invertebrates (Tippets and Moyle 1978) and will suffer if faced with an inadequate forage base caused by fluctuating flows.

The vulnerability to anglers of stocked rainbow trout and brown trout is a key factor influencing the size attained by each species (Boles 1969). Brown trout are typically less vulnerable (Pawson 1991) and reside in the system for longer periods of time. It is this attribute that often allows brown trout to obtain greater size when compared to rainbow trout. However, Weiland and Hayward (1997) reported that stocking rates, not species vulnerability, were more important in determining the maximum size reached by rainbow trout and brown trout. They noted that overstocking ultimately destroyed the forage base for trout in a Missouri reservoir.

Water temperatures are a major factor regulating trout growth and survival in tailwaters. The pulsing of cold, hypolimnetic water drastically alters temperature regimes and directly affects downstream fauna. Changes in water temperature affected the rate of consumption by brown trout in studies by Jensen and Berg (1993; 1995). A sudden drop in temperature (5.2 C) over a 16-h period reduced consumption rates and resulted in the smallest intake of rations that was observed. The optimum temperature for trout growth



will vary among species and sizes of fish, but Elliot (1975) noted that adult brown trout grew fastest between 10 and 15 C. Appropriate water temperatures must be present year-round to maintain a quality trout fishery; water temperatures above 23 C can be lethal to rainbow trout (Cherry et al. 1977; Biagi and Brown 1997). However, the thermal acclimation state of an individual ultimately determines the response of the individual to changing temperatures (Brett 1956).

Stream depth and water velocity, which are important habitat variables related to trout growth and survival, are governed by rates of water discharge (Shirvell and Dungey 1983). Large woody debris and other critical habitat structures preferred by trout may be washed out or dewatered as a result of fluctuating flows. Artificial flow regimes also decrease habitat stability by reducing the quality and quantity of available habitat types within a system (Pert and Erman 1994).

The Hiwassee River below Apalachia Powerhouse in southeast Tennessee has been a popular trout fishery for several decades. Each year, the river is stocked with about 100,000 catchable (> 200 mm total length, TL) rainbow trout and about 17,500 catchable brown trout. Little information exists on the fate of these fish because the Hiwassee River is difficult to sample using traditional techniques. Extensive shoals and whitewater rapids prevent rigid boats from traversing many reaches and the water is too deep and swift to wade with backpack electrofishing gear in other reaches. Bettoli (1989) conducted a creel survey in the mid-1980s and noted low return rates for trout stocked into the Hiwassee River. In recent years, high summer temperatures have been problematic and are thought to limit the trout fishery (F. Fiss, Tennessee Wildlife Resources Agency, personal communication). The objectives of this study were to: (1) estimate the population size and biomass of holdover trout in the Hiwassee River; (2) measure the growth, survival and condition of stocked trout; (3) determine rainbow trout resistance time to equilibrium loss at different temperatures; (4) map the habitat and evaluate the water quality in the tailwater; and (5) estimate fishing pressure and harvest rates.

## STUDY AREA

Apalachia Dam is located on the Hiwassee River (HR) at river kilometer 106 (HRkm 106) in Cherokee County, North Carolina, approximately 50 km east of Cleveland, Tennessee. The Tennessee Valley Authority (TVA) completed construction of the dam in 1943 and it impounds Apalachia reservoir. At normal pool the reservoir has a surface area of 440 ha and a drainage area of 1,638 km<sup>2</sup>. Unlike most tailwater systems, the discharge from Apalachia Dam enters an aqueduct and is piped approximately 14 km downstream to the Apalachia Powerhouse at HRkm 86.2 in Polk County, Tennessee (Figure 1). At full generation, this two-turbine facility releases approximately 80 m<sup>3</sup>/s (2,850 cfs) with an additional flow of approximately 2 m<sup>3</sup>/s (80 cfs) from the old river channel (Williams 1997).

The Hiwassee River harbors both warmwater and coldwater species; however, salmonids are the dominant sportfish species in the tailwater. Rainbow trout and brown trout accounted for 97 percent of the fish harvested in 1995 (Scott et al. 1996). State trout regulations allow anglers to harvest seven trout daily on the Hiwassee River in all areas

other than the Quality Zone, a 6-km section in the upper reach of the tailwater (Figure 2). Quality Zone regulations include a 35.6 cm (14 inch) minimum length limit and a daily limit of two trout. Also, the use of any bait other than artificial lures is prohibited in the Quality Zone.

Historically, high water temperatures and low dissolved oxygen (DO) levels (< 6mg/l) occurring in late summer and early fall and were considered to be limiting the trout populations in the Hiwassee River (Scott et al. 1996). To alleviate these problems, TVA implemented a year round minimum flow regulation (6 m<sup>3</sup>/s; 200 cfs) in 1991, which is accomplished by pulsing one of the two turbines for one hour every four hours. Also, hub baffles were installed on the turbines in 1993 to aerate the discharge (Scott et al. 1996). These modifications were successful and reduced the number of deficit days (number of days that the target DO level of 6 mg/l was not met, multiplied by the number of mg/l below the target level) from 54 d to less than 1 d (Scott et al. 1996; Figure 3).

The upper section of the tailwater below Apalachia Powerhouse is classified as a Class II whitewater river and receives heavy non-angling recreational use during the summer months. This area is also the only section of the tailwater that provides easy access for bank fishing and suitable depths for wading during periods of no generation. The conflicting interests of anglers and rafters are thought to have a direct effect on the amount of fishing pressure this area receives during the summer months (Bettoli 1989).

In 1995, TVA initiated a minimum flow consisting of full generation between 11 AM and 7 PM from Memorial Day until the end of August to benefit canoeist and rafters. It is unknown what effect, if any, these new minimum flows have had on the trout fishery.

## **METHODS**

### **Trout Marking**

The Tennessee Wildlife Resources Agency (TWRA) stocked the Hiwassee River with approximately 100,000 catchable rainbow trout in four monthly cohorts between 14 January and 22 July 1999. One cohort of catchable brown trout (n = 17,870) was stocked on 31 March and 1 April 1999 (Table 1). A subsample of about half of each monthly rainbow trout cohort, and all the brown trout, were marked using Mark IV CWT microtagging units manufactured by Northwest Marine Technology. Each cohort was microtagged in a different anatomical location and the adipose fin of all tagged fish was clipped (Table 2). Prior to stocking and at least 30 days after tagging, about 2% of the fish in each cohort were measured for total length (mm), weight (g), and checked for retention of the microtag. To reduce the amount of stress on the fish, clove oil was used as an anesthetic during all handling (Anderson et al. 1997).

### **Trout Stocking and Sampling**

All trout cohorts, with the exception of the caudal fin-tagged brown trout and anal fin-tagged rainbow trout, were stocked at normal TWRA stocking locations (Figure 4) between 27 January and 9 July 1999 (Table 2). The caudal fin-tagged brown trout and the

anal fin-tagged rainbow trout were placed in livewells on whitewater rafts and stocked exclusively into the Quality Zone on 31 March and 8 June, respectively.

Fifteen sampling transects were established in two strata (Figure 2). Strata 1 (the upper 9.5 kilometers located between the Apalachia Powerhouse and Reliance, TN) contained two transects in each of two reaches. One reach began at the powerhouse and ended at the top of the Quality Zone; the other reach was the Quality Zone. The specific course taken during each transect within each reach was not fixed; electrofishing times for each transect were recorded. In strata 2 (the 20.5 kilometers of tailwater between Reliance and Patty Bridge) each of the eleven transects was fixed and sampled for 600 seconds.

The upper section (Strata 1) was sampled with a 3.7-m SOTAR whitewater raft based on a design provided by the Wyoming Game and Fish Department. This raft was custom-built for electrofishing and used DC supplied by a 2.5 GGP Smith-Root electrofishing system. A jet-driven electrofishing boat with the same Smith-Root electrofishing system was used to sample stations in the lower section (strata 2). Beginning on 3 February 1999, samples were collected approximately monthly during daylight hours at full generation ( $\geq 637 \text{ m}^3/\text{s}$ ). Drought conditions and low discharge levels prevented us from sampling the river in April or May 1999 (Figure 5).

All trout collected during each electrofishing transect were placed in an aerated tank and anesthetized with clove oil. Total length (mm) and weight (g) were recorded for all fish and each fish was checked for the presence of a microtag using a detection wand before being released.

## Population Estimates

The number of holdover brown trout and rainbow trout was estimated in late winter in 1999 and 2000. A holdover fish was defined as any trout residing in the Hiwassee River prior to the first stockings in 1999 and 2000. The number of trout was estimated using the change-in-ratio technique (Paulik and Robson 1969):

$$N_1 = R_x - P_2 R / (P_2 - P_1);$$

where  $N_1$  is the total population at time 1 (i.e.; before stocking),  $R_x$  is the net change in the number of tagged trout in the tailwater (equals the number of tagged rainbow trout tagged in January),  $R$  is the net change in the number of trout in the tailwater (equal to  $R_x$ ),  $P_2$  is the proportion of tagged trout in the tailwater at time 2 (i.e.; when the sample is taken), and  $P_1$  is the proportion of tagged trout in the tailwater at time 1 (i.e.; before stocking). Key assumptions for the CIR technique are (1) marks or tags are not lost; (2) mixing between marked and unmarked organisms occurs; (3) marks or tags do not increase organisms susceptibility to recapture; (4) marks or tags do not cause mortality; (5) the system has geographic closure.

Variance of the population estimates were calculated following Paulik and Robson (1969):

$$V(N_1) = (P_2 - P_1)^{-2} [N_1^2 V(P_1) + (N_1 + R)^2 V(P_2) + (1 - P_2)^2 V(R_x) + P_2^2 V(R_y)];$$

where  $V$  is the variance and  $R_y$  is the change in the number of holdover trout (i.e.; zero).

The biomass of holdover brown trout and rainbow trout was calculated using the following equation:

$$B = (W_i H_t) / A;$$

where  $B$  is the biomass of holdover trout,  $W_i$  is the mean weight (kg) of holdover trout (i.e.; brown, rainbow, or both species),  $H_t$  is the number of holdover trout (i.e.; population estimate for each species, or both species combined), and  $A$  is the area of the study reach, in hectares.

The first CIR experiment began when 11,136 rainbow trout microtagged below the dorsal fin were stocked on 27 January 1999 at the standard TWRA stocking sites. Some of these fish were also stocked by boat in areas with limited road access between Reliance and Patty Bridge to ensure an equal distribution of marked fish along the entire tailwater. The census sample was collected with electrofishing gear on 3 February 1999 and trout were noted as being marked or unmarked. Prior to this CIR experiment, unmarked rainbow trout ( $n = 8,123$ ) were inadvertently stocked earlier in January, before the tagged fish were released. Therefore, that number (8,123) was subtracted from the 1999 population estimate to estimate the number of holdover rainbow trout at the beginning of the 1999 fishing season.

The CIR experiment was repeated in January 2000. Rainbow trout marked with an adipose fin clip ( $n = 11,427$ ) were stocked on 17 January 2000 using the same protocols as in January 1999. A census sample was subsequently collected on 20 January 2000.

### **Habitat Mapping and Water Quality**

Using a Global Positioning System (GPS) receiver and computer software (ARC/INFO 1995; ArcView 1995), a Geographical Information System (GIS) map was developed for the habitat units of the Hiwassee tailwater in the spring of 1999. The entire study reach (30 km) was traversed on foot and by canoe during periods of base flow (i.e., no generation) and reference points were taken with a GPS receiver at each riffle, run, pool, and shoal habitat unit. Habitat units were defined based on visual observation. Relatively shallow areas with fast moving turbulent water were classified as riffles. Habitat units with moderately deep water and swift but non-turbulent flow were classified as runs; pools were recorded as deep-water areas with little flow or turbulence. A shoal was defined as any area that contained exposed, inverted bedrock resulting in numerous pool, riffle and run microhabitat units. Surface area ( $\text{km}^2$ ), mean width, and length of each habitat unit were calculated using GIS.

Temperature loggers that recorded the temperature every 30 minutes were placed at three sites in the river (Apalachia Powerhouse, Childres Creek, Patty Bridge) from July through December 2000. Water quality parameters were measured using a Hydrolab® Scout® 2 water quality data system. Three replicate water samples were collected in January 2000 at the sites where temperature loggers were placed and assayed for alkalinity.

## Temperature Tolerance

Approximately 125 rainbow trout (> 200 mm total length, TL) were transported from Dale Hollow National Fish Hatchery and placed into a dual-tank recirculating system (Figure 6) on 22 February 2000. The holding tanks had a combined volume of approximately 3,400 liters. Water temperature was regulated using a chilling unit and ranged from 9.2 C to 10.2 C.

Stocking simulations were conducted by removing four fish from the holding tanks and placing them into a 114-l test tank (Figure 7). Trout were subjected to test temperatures of 18, 21, 24 and 27 C and temperatures were held constant using three 120-V heaters and a thermostat. The order of the trials at each temperature was randomly determined and two replicates were conducted at each temperature.

Prior to the start of a trial, water quality parameters (dissolved oxygen, temperature and ammonia levels) were measured in the holding tanks and test tank. Visual observations of trout placed in the test tank were recorded for one hour. Times were recorded when partial or complete loss of equilibrium occurred. Partial loss of equilibrium was defined as a swimming motion which resulted in an individual orienting itself perpendicular to the surface; complete loss of equilibrium was recorded when an individual rolled over on its back. Any fish that completely lost its equilibrium for more than 30 seconds was immediately removed from the test tank. Individual fish were not tested more than once. Resistance time (elapsed time) was recorded for all observations and all fish were weighed (g) after they were removed.

## Creel Survey

A stratified non-uniform probability roving creel survey was conducted between 30 January 1999 and 20 November 1999. The survey was designed to collect information on the amount of fishing pressure the tailwater was receiving, the catch and harvest rates of marked and unmarked rainbow trout and brown trout, and the catch per unit of effort for both species.

The survey was divided into 21 two-week periods. Normally, four weekdays and all weekend days were surveyed in each two-week period. Sampling days were divided into equal work periods based on sunrise and sunset times. The river was stratified into two areas: the powerhouse to Reliance was Area 1 and the reach from Reliance to the new Patty Bridge was Area 2. Area 1 was sampled with a probability of 60% during the first eight periods of the survey (January – early May) and 70% thereafter; these probabilities reflected expected (and observed) differences in fishing pressure between the areas. The AM and PM work periods were sampled with equal probability during periods 1-9 and periods 17-21; during the summer months (periods 10 –16) the AM period was sampled with 60% probability. The clerk counted anglers in the area being surveyed once each work shift. The time to start the count was randomly selected from a list of possible start times for each shift, beginning at daylight (or midday) and every 30 minutes thereafter until 1 h before the end of the shift. The counts were adjusted upwards when more boat/raft trailers were counted than boats by adding the mean number of anglers per boat for each boat that was presumed to be on the river, but was not observed.

Before and after the count, the clerk interviewed anglers. If anglers agreed to be interviewed, they were asked how long they had been fishing that day, whether they were finished fishing, and how many trout they had caught. Anglers were asked their state of residency and Tennessee residents were also asked for their county residence. The clerk also recorded the method of fishing used by each angler. Finally, the clerk, who was equipped with a tag detection wand, examined the catch of each angler to see if any tagged fish were harvested and measured their lengths. A copy of the interview sheet is provided in Appendix I.

Mean daily counts were expanded to estimate effort in each stratum (i.e., kind-of-day), then pooled to estimate effort during each two-week period following the methods of Pollock et al. (1994). Catch and harvest rates were measured using the mean of ratios method, which is recommended for roving creel surveys (Pollock et al. 1997); interviews of parties that had been fishing for less than 30 minutes were excluded from the analysis. Catch and harvest of each trout species, and each tagged cohort, were then estimated for each two-week period. Standard errors of catch, harvest, and effort each two-week period were calculated according to Pollock et al. (1994). A spreadsheet performed all necessary calculations and calculated 95% confidence intervals around each estimate of catch, harvest, and effort. The pooled variance for total pressure, total harvest, and total catch of each species was calculated using the mean-square-successive-difference-between-periods procedure. The square root of the variance was doubled and then added and subtracted to the estimates to generate approximate 95% confidence intervals.

The average number of trout harvested by complete-trip anglers and incomplete-trip anglers was compared using the Wilcoxon rank-sum test. Complete-trip and incomplete-trip anglers did not differ in the rates at which they harvested trout (both species combined;  $P = 0.37$ ); therefore, the data from all interviews were pooled.

The results of this survey were compared to similar surveys conducted on the South Fork of the Holston, Clinch, Caney Fork and Watauga rivers (Bettoli and Bohm 1997; Bettoli 1999; Devlin and Bettoli 1999; Bettoli et al. 1999). These four rivers have been shown to be among the most popular tailwater trout fisheries in Tennessee. The results of this survey were also compared to creel survey results obtained for the Hiwassee River when it was surveyed in 1987 (Bettoli 1989).

## **Data Analysis**

Catch curve analysis was used to estimate the survival of each cohort. Catch data collected during monthly electrofishing samples were transformed ( $\log_e [\text{catch}+1]$ ) and regressed against days post-stocking using software written for the Statistical Analysis System (SAS Institute 1982). Annual and 200-d survival rates were estimated using antilogs of the instantaneous rate of mortality ( $Z$ ; slope). Survival could not be mathematically estimated for the rainbow trout stocked in March because too few of those fish were subsequently collected. A pairwise test of the homogeneity of slopes was performed to compare survival rates among cohorts (SAS Institute 1982); survival was considered similar at  $P \geq 0.10$ .

Growth of each cohort was calculated by regressing individual length and weights against days post-stocking using software written for the Statistical Analysis System (SAS

Institute 1982). Growth was considered significant if the slope of the regression line differed from zero ( $P \leq 0.10$ ).

## RESULTS

### Survival

Brown trout that were microtagged and stocked into the Hiwassee River below Apalachia Powerhouse were collected in all subsequent electrofishing samples (Table 3). The 200-d survival of this cohort was 12.7% (Figure 8). Catch of the January and June rainbow trout cohorts approached zero at 168 and 128 days post-stocking, respectively. The January rainbow trout cohort was observed through July and the 200-d survival was 4% (Figure 8). Rainbow trout stocked in June were observed through October with a 200-d survival of 3% (Figure 8). However, only four fish from the June rainbow trout cohort were collected after 34 days in the river (Table 3). Rainbow trout stocked in July persisted through the end of the study and their 200-d survival was 4% (Figure 8). However, similar to the May rainbow trout cohort, only seven July rainbow trout were collected after 37 days in the river.

Brown trout had a significantly higher survival rate than the January and June cohorts of rainbow trout ( $P = 0.09$  and  $0.01$ , respectively). Rainbow trout stocked in July survived at the same rate as brown trout ( $P = 0.21$ ). Rainbow trout survival rates were similar among cohorts and uniformly low ( $P = 0.88$ , Figure 8).

### Growth

Brown trout grew slowly in the Hiwassee River. Two brown trout that we collected in the summer of 1999 had adipose fin-clips, which identified them as fish stocked by the Tennessee Valley Authority in the spring of 1995 at an average size of 195 mm and 89 g. After five growing seasons in the tailwater, these fish averaged only 401 mm in total length. Microtagged brown trout stocked into the tailwater on 31 March 1999 grew in total length ( $P = 0.04$ ) for the first 100 days post-stocking; however, growth subsequently ceased (Figure 9). When stocked, the microtagged brown trout averaged 193 mm (range: 145 - 240 mm) and 83 g (range: 37 - 162 g) (Table 2). Eight months later, these fish averaged only 242 mm TL and 120 g.

Microtagged and holdover brown trout collected in 1999 ( $n = 301$ ) ranged in size from 109 mm to 630 mm TL (Figure 10). Large holdover brown trout (TL  $\geq 356$  mm) were scarce; only 25% of the 149 holdover brown trout collected in 1999 were 356 mm long or longer and only 4% were longer than 408 mm. Most (61%) of large brown trout were collected in the Quality Zone.

Rainbow trout longer than 306 mm were rare; the few we observed were collected near the powerhouse in the fall of 1999. Tagged and untagged rainbow trout collected in electrofishing samples in 1999 ( $n = 283$ ) ranged from 126 to 365 mm TL (Figure 11). Only two of the four cohorts of rainbow trout stocked in 1999 exhibited significant growth. The January cohort grew 5.1 mm per month ( $P = 0.02$ ); however, significant weight gains were not observed ( $P = 0.26$ ). Rainbow trout stocked in March and June did not grow

significantly in either length or weight ( $P \geq 0.10$ ), but fish stocked in July grew 7.5 mm and 54 g per month ( $P \leq 0.04$ ). The growth analysis for those rainbow trout stocked in July was strongly influenced by a small number of recaptures collected near the Apalachia Powerhouse. During late summer, clupeids were being entrained at either Apalachia or Hiwassee Dams and eventually released through the turbines at the powerhouse. A cursory analysis of stomach contents of rainbow trout occupying the Hiwassee River below the powerhouse revealed that they were utilizing this abundant forage base, which resulted in rapid growth. When trout collected at the powerhouse were excluded from analysis, the July cohort did not exhibit significant growth in total length ( $P = 0.21$ ) and they actually lost weight over time.

### **Standing Crops**

The 1999 census sample that was collected to estimate the population size of holdover trout resulted in the capture of 65 trout, 19 of which were microtagged; thus the population estimate was 26,961 holdover trout (Table 4). However, after correcting for the 8,123 rainbow trout stocked prior to the census sample, the actual number of holdover trout in the system was 18,838 or 61/ha. Rainbow trout were collected at all but three of the lower sampling stations; brown trout were not collected below the Quality Zone. Brown trout made up 75% ( $n = 14,067$ ) of all holdover trout.

The CIR technique was repeated on 20 January 2000 and resulted in a population estimate only one-third of the 1999 estimate. Seventy-three trout were collected, 46 of which were microtagged, resulting in a population estimate of 6,707 trout or 22/ha (Table 4). Most of the trout were collected in the upper section of the tailwater above Reliance. On the lower section, brown trout were only observed at two transects and rainbow trout at only four of the eleven transects sampled. Similar to the 1999 survey, brown trout made up 81% ( $n = 5,465$ ) of all holdover trout in the tailwater. Brown trout stocked in 1999 contributed 37% ( $n = 2,484$ ) to the number of holdover trout in January 2000 and the July cohort of rainbow trout contributed 7% ( $n = 497$ ).

Trout syanding crop estimates in 1999 and 2000 were only 20 kg/ha and 13 kg/ha, respectively (Table 4). When compared to estimates for other tailwater trout fisheries in Tennessee, the Hiwassee River estimates ranked last (Figure 12). Those estimates were also lower than the average standing crops Region IV biologists measure on small wild trout streams (31 kg/hectare; Habera et al. 2000).

### **Creel Survey and Return Rates**

During the 1999 survey period, we interviewed 964 fishing parties, representing 1,844 anglers. Fishing pressure during the 1999 survey period was estimated at 73,842 hours (Table 5). Over comparable periods (March-November), fishing pressure in 1999 was 30% higher than in 1987 (Bettoli 1989). Anglers reported catching 58,717 rainbow trout and 14,453 brown trout, of which 37% (21,828) and 11% (1,631) were harvested, respectively (Table 5). In contrast to survey results from 1987 and 1988 (Bettoli 1989), there was an inverse relationship ( $P = 0.0006$ ,  $r^2 = 0.47$ ) between average daily discharge during each two-week creel period and fishing pressure in 1999 (Figure 13). Fishing pressure peaked in late March (period 5) and remained high ( $\geq 5,000$  hours) through mid-



June (period 10; Figure 14). That peak in fishing pressure coincided with baseflow conditions in late spring. An estimated 54% (39,685 h) of the fishing pressure during the survey occurred during that baseflow period. Also, most of the rainbow trout (63%) and brown trout (81%) that anglers reported catching over the entire survey were caught between 13 March and 18 June 1999.

To put fishing pressure on the Hiwassee River into perspective, we compared the pressure it received to other tailwaters surveyed in the 1990s during similar 26-week periods. To account for large differences in surface area (at baseflow) among tailwaters, fishing pressure per week was divided by the total area actively managed for trout fishing in each tailwater, as follows:

| River        | Start of 26-week Survey | Total Pressure (h) | Pressure (h) per Hectare per week | Reference                |
|--------------|-------------------------|--------------------|-----------------------------------|--------------------------|
| Hiwassee     | 3/27/00                 | 59,380             | 7                                 | This study               |
| Hiwassee     | 3/29/87                 | 41,415             | 5                                 | Bettoli (1989)           |
| Elk          | 4/ 4/95                 | 14,340             | 10                                | Bettoli & Besler (1996)  |
| Clinch       | 3/30/96                 | 75,876             | 12                                | Bettoli & Bohm (1997)    |
| Watauga      | 3/28/98                 | 53,444             | 15                                | Bettoli (1999)           |
| Caney Fork   | 3/29/97                 | 61,853             | 17                                | Devlin & Bettoli (1999)  |
| Caney Fork   | 4/ 4/95                 | 74,534             | 21                                | Bettoli & Xenakis (1996) |
| S.F. Holston | 4/ 1/97                 | 84,119             | 36                                | Bettoli et al. (1999)    |

Significantly more anglers were counted in Area 1 than in Area 2, on both weekdays and weekends (Wilcoxon two-sample-tests;  $P = 0.018$  and  $0.001$ , respectively). Over all weekend days, instantaneous counts averaged 20.3 in Area 1 and 7.9 in Area 2. Fewer anglers, but the same pattern, were observed on weekdays. Few anglers were ever observed in the lower reaches of Area 2 (downstream of the Highway 411 bridge in Benton), even though that reach was stocked.

The clerk observed 1,211 rainbow trout in the creel, of which 485 were microtagged. Based on the expanded creel estimates, microtagged rainbow trout stocked in January 1999 were harvested at a high rate (54%), but return rates fell for tagged trout stocked in March (22%), June (5-7%), and July (7%; Table 6). Although 5% of the rainbow trout stocked into the Quality Zone in June were harvested, all were harvested outside the Quality Zone; 7% of the rainbow trout stocked outside the Quality Zone in June were harvested. The clerk observed 84 rainbow trout that were harvested in the Quality Zone, only one of which was legal size (i.e.,  $> 356$  mm TL).

The clerk observed only 94 brown trout in the creel; 20 brown trout were harvested in the Quality Zone, although none were legal-size. Based on the expanded creel estimates, microtagged brown trout stocked into the Quality Zone were harvested at a higher rate (18%; Table 6) than brown trout stocked outside the Quality Zone (1%;  $P < 0.05$ ); however, the pooled return rate for all brown trout stocked in 1999 was only 4%.

Anglers harvested an average of 1.15 fish per trip; most (67%) did not harvest any fish (Figure 15). Most (72%) anglers reported catching at least one trout per trip and the average number caught per trip was high (4.33 fish/angler). Seventy-eight percent of all anglers interviewed were Tennessee residents, followed by Georgia residents (13%, Figure 16). The surveyed section of the river lies entirely within the boundaries of Polk County, which is where 14% of the Tennessee residents we interviewed resided. Most of the Tennessee residents we interviewed lived in Bradley (32%), Hamilton (22%) and McMinn (17%) counties in southeast Tennessee. Most (61%) of the anglers we interviewed were fishing with artificial lures (i.e., flies, spinners, plugs, or spoons) instead of bait. Fly fishermen represented 30% of all the anglers we interviewed.

### **Habitat Survey and Water Quality**

A map was constructed using geographic information systems (GIS) software (Figures 17 and 18) and the surface area was determined for each individual habitat unit (Table 7). The pool-riffle-run-shoal ratio at baseflow was 1.2 : 0.9 : 1.0 : 1.0; however, pools and shoals accounted for 39% and 35% of the total surface area of the river, respectively. Pools and shoals averaged 400 and 275 m in length and 113 and 134 m in width, respectively. Runs represented 22% of the surface area of the tailwater, with an average length and width of 382 and 60 m, respectively. The 29 riffles averaged 63 m in both length and width and accounted for 4% of the total area.

The upper section of the tailwater (above Reliance) was dominated by pools and shoals; whereas, the lower section (Reliance to Patty Bridge) was comprised mainly of pool and run habitat units. Average width of the tailwater also differed between the upper and lower sections. The mean width of the upper section was 250 m, whereas the lower section was more constricted, with an average width of 60 m.

Daily maximum water temperatures and water temperature fluctuations between July and December 1999 are shown in Figures 19 and 20. Water temperatures exceeding 20 C were common in summer and fall throughout the river. Below Childres Creek (near Reliance), maximum water temperatures exceeded 22 C on most days in August and September (Figure 19). Average daily water temperatures increased 1.7 C between Apalachia Powerhouse and Childres Creek; water temperatures varied less than 1 C between Reliance and Patty Bridge from July through December 1999. The maximum temperature observed on the tailwater was 25 C at Childres Creek on 29 August 1999.

Daily water temperature fluctuations were the smallest, on average, at the Powerhouse (2.3 C) and largest at Childres Creek (3.2 C). However, the largest daily fluctuations (8 C) in water temperature were observed in late October near the Powerhouse.

Relative to other east Tennessee tailwaters, the Hiwassee River was low in dissolved ions and very soft (Table 8). Alkalinity (as CaCO<sub>3</sub>) was only 8-12 mg/L at three sites, and conductivity ranged between 41 and 47 µS/cm.

### **Temperature Tolerance**

Rainbow trout acclimated at 10 C did not exhibit full loss of equilibrium when immersed in water at 18 and 21 C. However, partial loss of equilibrium (perpendicular orientation to the surface) was observed at 21 C. At 24 C, trout experienced full

equilibrium loss after an average of 8 minutes ( $n = 8$ ;  $SE = 1:23$ ; Figure 21). Similarly, full loss of equilibrium was observed after 4.5 minutes ( $n = 8$ ;  $SE = 0:16$ ) when trout were placed into the 27 °C test tank.

Even though equilibrium loss (partial and full) was observed during test trials at 24 and 27 °C, only trout placed into the 27 °C test tank were unable to regain equilibrium. After losing equilibrium, the majority of rainbow trout tested at 24 °C quickly recovered and were able to maintain equilibrium through the rest of the trial. Only one fish tested at 24 °C failed to regain equilibrium after 30 seconds. Conversely, all fish tested at 27 °C were unable to regain and maintain equilibrium and they were removed from the test tank after an average of 17 minutes ( $n = 8$ ;  $SE = 2:56$ ).

## DISCUSSION

### Survival and Harvest

Brown trout have always exhibited better survival than rainbow trout in previously studied Tennessee tailwaters (Bettoli and Besler 1996; Bettoli and Bohm 1997; Bettoli 1999; Bettoli et al. 1999; Devlin and Bettoli 1999), and that was the case in the Hiwassee River. In terms of 200-d survival rates, brown trout survived better in the Hiwassee River (13%) than in the Elk River (2%), but brown trout survived much better in the Clinch (69%), South Fork of the Holston (56%), Watauga (46%), and Caney Fork (34%) rivers. Poor survival of tagged brown trout in the absence of substantial harvest (i.e., their return rate was only 4%) indicated that natural mortality was more important than fishing mortality in regulating survival of recently-stocked brown trout.

Rainbow trout also survived poorly in the Hiwassee River relative to other Tennessee rivers. Only in the Elk River did stocked rainbow trout survive at a lower rate over 200-d (0%) than in the Hiwassee River (3-4%). In contrast, 200-d survival rates of stocked rainbow trout ranged as high as 27% in the Watauga River, 24% in the South Fork of the Holston River, and 14% in the Caney Fork River. Low survival would be expected when return rates are high, but with the exception of fish stocked into the Hiwassee River in January 1999, return rates for all other rainbow trout cohorts were low (7 – 22%). As with brown trout, the combination of low return rates and poor survival clearly indicated that the force of natural mortality was much greater than fishing mortality in regulating the survival of recently-stocked rainbow trout.

Water temperatures were often too warm for trout growth and survival in the Hiwassee River below Apalachia Dam. Maximum water temperatures consistently exceeded 21 °C daily between mid-July and mid-October, depending on the location in the tailwater. In a laboratory study, Spigarelli and Thommes (1979) reported that rainbow trout strongly avoided temperatures exceeding 21 °C and preferred a temperature of approximately 19 °C. Lethal thermal conditions for trout can arise when water temperatures exceed 23 °C (Cherry et al. 1977; Biagi and Brown 1997). These temperatures were rare at the powerhouse; however, maximum water temperatures in September regularly exceeded 23 °C at Childres Creek and Patty Bridge. Thermal stress associated with high water temperatures during late spring and summer probably

influenced trout survival rates during stocking. Depending on the acclimation temperature of the trout when released, a rapid change in temperature can cause a response (equilibrium loss) that increases their vulnerability to predation and other sources of mortality.

Drought conditions in southeast Tennessee during the spring of 1999 resulted in extended periods of minimum flows and high water temperatures on the Hiwassee River below Apalachia Dam. In fact, water discharges through Apalachia Dam in 1999 were the lowest in 10 years (Figure 22). Coincident with the low flows and high temperatures were heavy fishing pressure and high catches of trout. Although most (70 – 80%) of the rainbow trout and brown trout reportedly caught during late spring and summer 1999 were released, hooking mortality may have been a factor in the poor survival that was observed during this study. In several studies, water temperature was a significant predictor of post-release mortality of trout (Dotson 1982; Schisler and Bergersen 1996), although Taylor and White (1992) did not detect such an effect in a meta-analysis of hooking mortality. Heavy fishing pressure and high catch rates during a time when water temperatures were high could have reduced the survival of trout stocked before and during base flow conditions.

Predation by striped bass *Morone saxatilis* and walleye *Stizostedion vitreum* may have influenced trout survival in the Hiwassee River. Striped bass in the Caney Fork River below Center Hill Dam, Tennessee, readily preyed on recently-stocked rainbow trout (Devlin and Bettoli 1999). Similarly, walleye are known to prey on stocked rainbow trout in tributary reservoirs in Tennessee (C. Vandergoot, Tennessee Technological University, personal communication). Striped bass and walleye were routinely encountered, albeit in small numbers, during the electrofishing samples; however, the numbers of trout lost to predation could not be quantified because the size of the predator populations was unknown. If predation was a factor, it would probably be most severe in the lower reaches of the tailwater (below Reliance), where the majority of these predators were observed.

## **Growth and Condition**

With the exception of some rainbow trout that were stocked in July, all trout stocked into the Hiwassee River grew slowly when compared those in other Tennessee tailwaters. Initially, brown trout growth on the Hiwassee River (8 mm/month) was comparable to growth on the Elk (6 mm/month), Watauga (6 mm/month), Caney Fork (8 mm/month), Clinch (11 mm/month), and South Fork of the Holston (11 mm/month) Rivers (Bettoli and Besler 1996; Bettoli et al. 1999; Devlin and Bettoli 1999). However, brown trout ceased growing on the Hiwassee River after about 100 days and, unlike in other tailwaters, weight gain was insignificant throughout the study. Two brown trout stocked as catchables in 1995 by the Tennessee Valley Authority were collected in 1999 and averaged only 401 mm TL. In comparison, brown trout stocked in the Caney Fork and Clinch Rivers reached total lengths of 325-350 mm in only one year (Bettoli and Bohm 1997; Devlin and Bettoli 1999). In the Caney Fork River, brown trout averaged 484 mm TL only 26 months post-stocking (Devlin and Bettoli 1999).

The January cohort of rainbow trout was the only group of trout that exhibited significant growth throughout the study, although it was slow (5mm/month). Although growth was significant for fish stocked in July, the growth rates were influenced by a few (n = 4) large individuals collected directly below the powerhouse. Those fish preyed on clupeids that were entrained at Apalachia Dam during generation. Utilizing this forage

base, some July rainbow trout exhibited excellent growth that was uncharacteristic of trout growth elsewhere in the river. If released elsewhere in the tailwater, that group of rainbow trout would likely have grown slowly. Excluding those large fish from analysis resulted in no growth in length and significant weight loss for trout stocked in July. In contrast, rainbow trout routinely display good or even excellent growth rates of up to 20 mm/month in other Tennessee tailwaters such as the Clinch River or South Fork of the Holston River (Bettoli and Bohn 1997; Bettoli et al. 1999). Similarly, rainbow trout in tailwaters around the country such as Flaming Gorge, UT (15 mm/month; Johnson et al. 1982); Missouri River, MT (7 mm/month; Kathrein 1950); Bighorn River (15 mm/month; Stevenson 1975); and White River, AK (20 mm/month; Aggus et al. 1979) grew at a faster rate than rainbow trout in the Hiwassee River.

The condition of stocked rainbow trout and brown trout in the Hiwassee River declined over time. This trend of declining condition of stocked trout is well documented (Reimers 1963; Ersbak and Haase 1983; Bachman 1984) and has been observed in other Tennessee tailwaters (e.g., Bettoli and Besler 1996; Devlin and Bettoli 1999). Hatchery fish, which are typically more robust and have a higher basal metabolic rate than wild or holdover trout, have difficulty satisfying their bioenergetic demands (Ersbak and Haase 1983).

There are several factors that determine the success of stocked trout and their ability to thrive in a new environment. They include behavioral adaptations, competition for food, food availability, habitat limitations, and water quality. Hatchery trout typically adapt quickly to natural prey items (Lord 1934; Raney and Lachner 1942; Ersbak and Haase 1983); however, they can be inflexible to seasonal changes in forage. For instance, resident brown trout in a Pennsylvania stream utilized expanding populations of Brachycentridae and Limnephilidae larvae (caddisflies), but stocked brook trout continued to utilize a diminishing population of Glossosomatidae (caddisfly) larvae (Ersbak and Haase 1983). The brook trout were apparently unable to recognize the new prey items and their condition suffered as a result. This delayed reaction to new and plentiful prey items creates a disadvantage for stocked trout when competing for food. In other rivers, hatchery trout moved more frequently than wild or naturalized trout (Bettinger and Bettoli 2000) and were less energy-efficient when feeding and competing for habitat (Bachman 1984).

A depauperate prey base caused by fluctuating flows can result in poor fish growth and condition (Brusven 1984; Odenkirk and Estes 1991; Weisburg and Burton 1993). The macroinvertebrate community in the Hiwassee River suffered in the spring of 1999 when much of the wetted area of the tailwater was dewatered for long periods of time. The pulsing of water during that time flooded the area directly below the powerhouse; however, areas downstream ( $\geq 3$  km) remained dewatered. Limited food availability may have been one reason why growth and condition of trout on the Hiwassee River was so poor. When sufficient prey (i.e., clupeids) were available below the powerhouse in the fall of 1999, some rainbow trout took advantage of the abundant forage and gained substantial weight. Further research on the effects of water fluctuation as it relates to the macroinvertebrate community and the growth and condition of trout in the Hiwassee River would be valuable.

## **Habitat and Water Quality**

The habitat in the upper reach of the Hiwassee River was considerably different compared to other Tennessee tailwaters (Bettoli 1999; Bettoli et al. 1999; Devlin and Bettoli 1999). Riffles were the predominant habitat in the South Fork of the Holston and Watauga rivers and cobble and gravel were observed throughout each tailwater. In the Caney Fork River, pools accounted for 90% of the surface area and riffles and runs were sparse (6% and 4%, respectively). Similarly, riffles were scarce on the Hiwassee River, accounting for less than 5% of the surface area. Bedrock was the predominant substrate on the Hiwassee River above Reliance, and the inverted bedrock in that section created shoal habitats. Within each shoal, there were numerous pool, riffle, and run microhabitats, and the majority of trout collected in this study were located in and around shoal habitats above Reliance. It appears that trout were using these shoals as resting and feeding areas during periods of high flow.

The habitat in the lower reach of the Hiwassee River below Reliance was more typical of habitat found in some other Tennessee tailwaters. Bedrock was less abundant and boulders and large woody debris were present. However, few trout were collected in the lower reaches and other environmental factors such as temperature were probably limiting trout abundance in the lower reaches on the Hiwassee River.

Alkalinity levels are used to predict biological productivity of trout streams in other locales (Scarnecchia and Bergersen 1987; Clarke and Scruton 1999). Based on its low ( $\leq 12\text{mg/L}$ ) alkalinity, the Hiwassee River was regarded as an infertile system (Banks and Bettoli 2000). The low productivity of the Hiwassee River was considered a major factor contributing to the poor growth, condition, and survival of stocked trout.

Elevated water temperatures have been a chronic problem limiting trout productivity in the Hiwassee River. Scott et al. (1996) observed that fish diversity (43 species) and fish species composition present in the Hiwassee River in 1993 was typical of warmwater streams in Tennessee. In contrast, other east Tennessee tailwaters (Clinch, Watauga, and South Fork of the Holston rivers) supported coldwater fish communities dominated by trout, with fewer (15-25) species (Scott et al. 1996; Habera et al. 1999, 2000). Although we did not collect or quantify non-trout species during our electrofishing samples, we noted that trout were outnumbered by other species, particularly in the reach below Reliance. As most of the species identified by Scott et al. (1996) were insectivorous or omnivorous (as are trout), interspecific competition for food resources may be intense in the Hiwassee River relative to other Tennessee tailwaters, which are usually dominated by trout.

## **Standing Crops**

The two estimates of population size and standing crop of holdover trout in the Hiwassee River were low when compared to those of other Tennessee tailwaters (Bettoli 1999; Devlin and Bettoli 1999). The infertile waters of the Hiwassee River may be an important reason why estimates of population size and biomass were consistently low. Kwak and Waters (1997) reported that salmonid production was positively correlated with alkalinity in Minnesota streams. In Tennessee, high standing crops of holdover trout

(112 - 232 kg/hectare) accompanied high alkalinity values ( $\geq 100\text{mg/L}$ ) in the Clinch and South Fork of the Holston rivers.

Natural reproduction did not contribute to trout standing crops in the Hiwassee River. The failure of brown trout and rainbow trout to reproduce in the Hiwassee River was due, in part, to the lack of appropriate habitat and substrate (Banks and Bettoli 2000). Although potential spawning areas were located at Childres Creek, high flows during the spawning season probably prevented any reproduction in that area. Two wild age-0 rainbow trout were collected during the summer of 1999; however, we concluded these fish were the product of reproduction which occurred in tributaries of the Hiwassee River. Even if appropriate substrates and water flows were present in the main river channel, few large adults were present in the system, and their reproductive fitness was low. In fact, brown trout fecundity in the Hiwassee River was substantially lower than in three other east Tennessee tailwaters (Banks and Bettoli 2000).

Fall stockings may remedy the poor survival and carry-over of rainbow trout in the Hiwassee River. Stocking rainbow trout in December 1997 resulted in a five-fold increase in the overwintering population of rainbow trout in the Caney Fork River (Devlin and Bettoli 1999). Summer-stocked rainbow trout in Convict Creek, California, suffered high mortality rates in the winter due to poor condition (Reimers 1963); however, robust fall-stocked trout were able to survive the winter and made a valuable contribution to the fishery the following spring.

## CONCLUSIONS

Growth and survival of brown trout and rainbow trout in the Hiwassee River were poor when compared to other tailwater systems. Factors that directly influenced trout growth and survival were high water temperatures and low water fertility; high rates of predation and hooking mortality may also have contributed to poor survival. As a result of these factors, the density and standing crop of holdover trout in the Hiwassee River were extremely low.

The drought conditions present in the Hiwassee River in 1999 undoubtedly contributed to the low standing crop of trout carrying over into January 2000. However, the standing crop of trout measured in January 1999, which reflected environmental conditions the previous year, was also very low, despite the fact that 1998 was a more typical year in terms of rainfall and discharge (Figure 22). The tailwater trout fishery in the Hiwassee River is sensitive to the amount of water discharged each summer because the water discharged from Hiwassee Dam (which then travels through Apalachia Dam) is warm. Even in average rainfall years (e.g., 1998), the water discharged from Hiwassee Dam will routinely exceed 18°C in late summer (TVA, unpublished data). On a typical summer day, that water warms as it passes through Apalachia Reservoir, the sluiceway, and the river below the powerhouse. In contrast, water discharged during summer at TVA facilities on other rivers managed for trout is much cooler (9°C below Norris Dam, 12°C below the South Fork of the Holston Dam, 9°C below Wilbur Dam on the Watauga River). In wet years, water temperatures in the Hiwassee River may not be an acute problem; in average or dry years, elevated water temperatures will strongly and negatively influence trout growth and survival. Additional studies are required to determine whether enough cold water can be stored in Hiwassee Reservoir to support healthy and robust trout populations in the Apalachia tailwater each summer and fall, given the current schedule of water releases.

We characterized trout growth and survival during a drought year; additional research on water temperatures and the fate of trout in this river during average or above-average rainfall years would be useful. In the interim, the following management actions should be considered:

1. Eliminate all stockings at and below Highway 411 because of high water temperatures, poor habitat, and low fishing pressure. Eliminate or severely reduce the number of trout stocked in late summer (August – September), and initiate winter stockings earlier (November or December).
2. When drought conditions are present, avoid stocking trout during extended periods of baseflow that can occur in spring months, when upstream reservoirs are being brought up to summer pool.
3. The Hiwassee River is unproductive and the amount of fishing pressure it receives is probably not high enough to warrant the stocking of nearly 120,000 catchable trout per year. A lower stocking rate should promote better growth and better rates of return to the creel. Stocking fewer fish would also be appropriate if stockings are limited to the upstream reaches of the tailwater.



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Table 1. Stocking date, number of fish, total weight and mean lengths of brown trout and rainbow trout stocked into the Hiwassee River during 1999.

| Species       | Date     | Strain <sup>1</sup> | Number Stocked | Total Weight (kg) | Mean Length (mm) |
|---------------|----------|---------------------|----------------|-------------------|------------------|
| Rainbow Trout | 01/14/99 | EED                 | 4,290          | 567               | 227              |
|               | 01/19/99 | EED                 | 3,833          | 550               | 234              |
|               | 01/27/99 | EED                 | 11,092         | 1,544             | 231              |
|               | 03/15/99 | EED                 | 9,975          | 1,570             | 241              |
|               | 03/17/99 | ARD, EED            | 3,885          | 547               | 233              |
|               | 03/22/99 | EED                 | 3,736          | 550               | 236              |
|               | 04/01/99 | ARD                 | 900            | 136               | 238              |
|               | 04/07/99 | ARD                 | 2,991          | 477               | 245              |
|               | 06/01/99 | ARD                 | 9,947          | 1,564             | 241              |
|               | 06/02/99 | ARD                 | 2,153          | 340               | 241              |
|               | 06/08/99 | ARD                 | 2,507          | 440               | 250              |
|               | 06/29/99 | ARD                 | 3,425          | 569               | 245              |
|               | 06/30/99 | ARD                 | 3,626          | 554               | 239              |
|               | 07/01/99 | ARD                 | 3,684          | 548               | 237              |
|               | 07/06/99 | ARD                 | 6,565          | 1,031             | 241              |
|               | 07/07/99 | ARD, FLD            | 3,552          | 544               | 233              |
|               | 07/08/99 | FLD                 | 4,181          | 553               | 227              |
|               | 07/12/99 | ARD, FLD            | 3,410          | 555               | 241              |
|               | 07/13/99 | ARD                 | 3,476          | 544               | 239              |
|               | 07/14/99 | ARD                 | 3,687          | 545               | 236              |
|               | 07/19/99 | ARD                 | 3,620          | 558               | 239              |
|               | 07/20/99 | ARD                 | 2,703          | 409               | 238              |
|               | 07/22/99 | ARD                 | 2,757          | 381               | 231              |
| Total         |          |                     | 99,995         | 15,082            |                  |
| Brown Trout   | 03/31/99 | PRD                 | 14,502         | 1,343             | 204              |
|               | 04/01/99 | PRD                 | 3,368          | 286               | 196              |
| Total         |          |                     | 17,870         | 1,630             |                  |

<sup>1</sup> Strain ARD = Arlee, EED = Erwin Arlee Backcross, FLD = Fish Lake Desmet, and PRD = Plymouth Rock Domestic.

Table 2. Number and size of brown trout and rainbow trout tagged and stocked into the Hiwassee River below Apalachia Powerhouse in 1999. Mean total length (TL, mm), mean weight (WT, g), and standard deviation (in parenthesis) were calculated using a subsample of approximately 20% of the total number tagged.

| Species | Cohort  | Tag location        | TL       | WT       | Number Tagged | Tag Retention (%) | Number Stocked | Date Stocked |
|---------|---------|---------------------|----------|----------|---------------|-------------------|----------------|--------------|
| Rainbow | January | Dorsal              | 206 (25) | 96 (32)  | 11,136        | 100               | 11,136         | 27 Jan       |
| Rainbow | March   | Caudal              | 243 (29) | 157 (46) | 11,137        | 97                | 10,803         | 16-17 Mar    |
| Rainbow | June    | Left Pectoral       | 247 (18) | 145 (33) | 12,071        | 97                | 11,709         | 1-2 June     |
| Rainbow | June    | Anal <sup>1</sup>   | 246 (16) | 144 (29) | 2,714         | 100               | 2,714          | 8 June       |
| Rainbow | July    | Snout               | 246 (22) | 153 (37) | 14,478        | 95                | 13,754         | 6-9 July     |
| Brown   | March   | Dorsal              | 192 (15) | 82 (30)  | 14,384        | 98                | 14,096         | 31 Mar       |
| Brown   | March   | Caudal <sup>1</sup> | 196 (15) | 88 (20)  | 2,719         | 95                | 2,583          | 31 Mar       |

<sup>1</sup> Trout stocked only into the quality zone of the Hiwassee River tailwater.



Table 3. Number of trout in each microtagged cohort collected on the Hiwassee River during 1999.

| Tag<br>Location      | Date<br>Stocked | 3-Feb | 2-Mar | 7-June | 25-June | 14-July | 12-Aug | 9-Sept | 7-Oct | 10-Nov | 9-Dec | Total |
|----------------------|-----------------|-------|-------|--------|---------|---------|--------|--------|-------|--------|-------|-------|
| <b>Rainbow Trout</b> |                 |       |       |        |         |         |        |        |       |        |       |       |
| Dorsal               | 27-Jan          | 19    | 29    | 5      | 3       | 2       | 0      | 0      | 0     | 0      | 0     | 58    |
| Caudal               | 16-Mar          | -     | -     | 2      | 3       | 5       | 1      | 0      | 0     | 0      | 0     | 11    |
| Anal <sup>1</sup>    | 8-June          | -     | -     | -      | 4       | 2       | 2      | 1      | 1     | 0      | 0     | 10    |
| L. Pectoral          | 1-June          | -     | -     | 16     | 5       | 5       | 0      | 0      | 0     | 0      | 0     | 26    |
| Snout                | 6-July          | -     | -     | -      | -       | 22      | 14     | 1      | 4     | 1      | 1     | 43    |
| <b>Brown Trout</b>   |                 |       |       |        |         |         |        |        |       |        |       |       |
| Dorsal               | 31-Mar          | -     | -     | 25     | 25      | 12      | 8      | 11     | 5     | 2      | 4     | 92    |
| Caudal <sup>1</sup>  | 31-Mar          | -     | -     | 19     | 16      | 6       | 4      | 6      | 3     | 4      | 2     | 60    |

<sup>1</sup> Stocked in Quality Zone

Table 4. Change-in-ratio population and biomass estimates for rainbow trout and brown trout in the Hiwassee River. Biomass estimates are calculated for the 321 hectare tailwater below the Apalachia Powerhouse. Confidence limits (95%) are in parentheses.

| Species              | Number of<br>Marked Fish<br>Stocked | Size of<br>Census<br>Sample | Number of<br>Recaptures | Number of<br>Unmarked<br>Fish | Population<br>Estimate | Variance          | Holdovers | Mean<br>Weight (g) | Biomass<br>(kg/ha) |
|----------------------|-------------------------------------|-----------------------------|-------------------------|-------------------------------|------------------------|-------------------|-----------|--------------------|--------------------|
| <b>February 1999</b> |                                     |                             |                         |                               |                        |                   |           |                    |                    |
| Both                 | 11,136                              | 65                          | 19                      | 46                            | 26,961                 | $5.4 \times 10^7$ | 18,838    | -                  | 20 <sup>1</sup>    |
| Rainbow              | 11,136                              | 41                          | 19                      | 22                            | 12,894                 | $1.6 \times 10^7$ | 4,771     | 118                | 2                  |
| Brown                | 11,136                              | 43                          | 19                      | 24                            | 14,067                 | $1.9 \times 10^7$ | 14,067    | 414                | 18<br>(7 – 29)     |
| <b>January 2000</b>  |                                     |                             |                         |                               |                        |                   |           |                    |                    |
| Both                 | 11,427                              | 73                          | 46                      | 27                            | 6,707                  | $2.6 \times 10^6$ | 6,707     | 610                | 13<br>(7 – 19)     |
| Rainbow              | 11,427                              | 51                          | 46                      | 5                             | 1,242                  | $3.4 \times 10^6$ | 1,242     | 573                | 2<br>(0.1 - 4)     |
| Brown                | 11,427                              | 68                          | 46                      | 22                            | 5,465                  | $2.0 \times 10^6$ | 5,465     | 618                | 11<br>(5 – 16)     |

<sup>1</sup> – Biomass of both species combined is equal to the sum of the individual biomass estimates for each

Table 5. Summary of the creel survey conducted on the Hiwassee River below Apalachia Powerhouse, 30 January 1999 – 20 November 1999. Values in parentheses are standard errors.

| Period | Start of Period | Pressure (Hours) | Estimated Catch  |                  | Estimated Harvest |              | Catch-per-hour<br>All Trout | N  |
|--------|-----------------|------------------|------------------|------------------|-------------------|--------------|-----------------------------|----|
|        |                 |                  | Rainbow          | Brown            | Rainbow           | Brown        |                             |    |
| 1      | 1/30/99         | 2,205<br>(814)   | 3,575<br>(1,735) | 255<br>(229)     | 1,917<br>(716)    | 28<br>(28)   | 1.53<br>(0.49)              | 24 |
| 2      | 2/13/99         | 1,680<br>(703)   | 4,122<br>(2,664) | 118<br>(77)      | 2,229<br>(1,801)  | 106<br>(89)  | 2.44<br>(0.62)              | 26 |
| 3      | 2/27/99         | 1,939<br>(562)   | 1,442<br>(543)   | 786<br>(733)     | 534<br>(239)      | 37<br>(22)   | 0.94<br>(0.23)              | 44 |
| 4      | 3/13/99         | 5,235<br>(1,016) | 8,153<br>(1,995) | 176<br>(167)     | 1,667<br>(840)    | 83<br>(83)   | 1.21<br>(0.3)               | 42 |
| 5      | 3/27/99         | 8,307<br>(1,148) | 5,328<br>(2,266) | 2,016<br>(1,244) | 1,999<br>(612)    | 270<br>(199) | 1.29<br>(0.21)              | 63 |
| 6      | 4/10/99         | 7,461<br>(2,843) | 9,335<br>(4,551) | 4,627<br>(2,989) | 2,257<br>(963)    | 104<br>(79)  | 1.37<br>(0.23)              | 72 |
| 7      | 4/24/99         | 6,338<br>(2,924) | 5,090<br>(3,100) | 1,913<br>(1,711) | 1,225<br>(555)    | 119<br>(98)  | 0.86<br>(0.14)              | 58 |
| 8      | 5/8/99          | 5,651<br>(708)   | 4,374<br>(856)   | 1,242<br>(568)   | 2,068<br>(850)    | 488<br>(416) | 0.99<br>(0.26)              | 57 |
| 9      | 5/22/99         | 6,710<br>(1,396) | 2,628<br>(958)   | 1,242<br>(448)   | 682<br>(225)      | 121<br>(44)  | 0.75<br>(0.19)              | 60 |
| 10     | 6/5/99          | 5,218<br>(704)   | 1,911<br>(230)   | 502<br>(141)     | 1,102<br>(240)    | 142<br>(57)  | 0.55<br>(0.12)              | 66 |
| 11     | 6/19/99         | 3,283<br>(729)   | 1,925<br>(597)   | 162<br>(66)      | 1,080<br>(222)    | 18<br>(11)   | 0.75<br>(0.16)              | 55 |

Table 5. (Continued)

| Period | Start of Period | Pressure (Hours)  | Estimated Catch   |                   | Estimated Harvest |                | Catch-per-hour<br>All Trout | N   |
|--------|-----------------|-------------------|-------------------|-------------------|-------------------|----------------|-----------------------------|-----|
|        |                 |                   | Rainbow           | Brown             | Rainbow           | Brown          |                             |     |
| 12     | 7/3/99          | 3,435<br>(1,259)  | 1,849<br>(659)    | 183<br>(55)       | 1,407<br>(693)    | 43<br>(38)     | 0.59<br>(0.09)              | 61  |
| 13     | 7/17/99         | 3,417<br>(757)    | 2,455<br>(603)    | 322<br>(141)      | 1,539<br>(481)    | 0              | 0.96<br>(0.16)              | 63  |
| 14     | 7/31/99         | 2,214<br>(525)    | 1,341<br>(704)    | 149<br>(51)       | 321<br>(124)      | 29<br>(17)     | 0.85<br>(0.16)              | 53  |
| 15     | 8/14/99         | 3,162<br>(915)    | 2,036<br>(784)    | 121<br>(67)       | 793<br>(242)      | 32<br>(28)     | 0.54<br>(0.11)              | 66  |
| 16     | 8/28/99         | 2,549<br>(578)    | 1,171<br>(538)    | 273<br>(139)      | 454<br>(198)      | 0              | 0.63<br>(0.12)              | 48  |
| 17     | 9/11/99         | 1,635<br>(387)    | 361<br>(178)      | 62<br>(47)        | 44<br>(31)        | 0              | 0.38<br>(0.16)              | 27  |
| 18     | 9/25/99         | 1,366<br>(471)    | 730<br>(223)      | 202<br>(171)      | 299<br>(124)      | 11<br>(11)     | 0.78<br>(0.15)              | 28  |
| 19     | 10/9/99         | 342<br>(128)      | 213<br>(127)      | 28<br>(28)        | 66<br>(66)        | 0              | 0.93<br>(0.29)              | 12  |
| 20     | 10/23/99        | 978<br>(450)      | 343<br>(229)      | 13<br>(10)        | 145<br>(120)      | 0              | 0.33<br>(0.11)              | 26  |
| 21     | 11/6/99         | 717<br>(250)      | 335<br>(199)      | 61<br>(41)        | 0                 | 0              | 0.6<br>(0.27)               | 15  |
|        | TOTALS          | 73,842<br>(5,156) | 58,717<br>(7,454) | 14,453<br>(3,215) | 21,828<br>(2,413) | 1,631<br>(439) | 0.9<br>(0.05)               | 966 |

Table 6. Survival and harvest of microtagged cohorts of rainbow trout and brown trout stocked in the Hiwassee River below Apalachia Powerhouse. Survival rates were not calculated for the March rainbow trout cohort due to low number of recaptures (n = 10).

| Species       | Cohort                  | Date stocked | Number stocked | 200-day Survival Rate % | Survival Through 20 January 2000 | Estimated Harvest (SE) | Percent Harvest |
|---------------|-------------------------|--------------|----------------|-------------------------|----------------------------------|------------------------|-----------------|
| Rainbow Trout | January                 | 1/27/99      | 11,136         | 4.3                     | 0.3                              | 5,961                  | 54              |
|               | March                   | 3/16/99      | 10,803         | -                       | -                                | 2,345                  | 22              |
|               | June                    | 6/1/99       | 11,709         | 2.8                     | 1.5                              | 840                    | 7               |
|               | June (QZ) <sup>1</sup>  | 6/8/99       | 2,714          | N/A <sup>2</sup>        | N/A <sup>2</sup>                 | 134                    | 5               |
|               | July                    | 7/6/99       | 13,754         | 3.6                     | 3.7                              | 998                    | 7               |
| Brown Trout   | March                   | 3/31/99      | 14,096         | 12.7                    | 4.8                              | 147                    | 1               |
|               | March (QZ) <sup>1</sup> | 3/31/99      | 2,583          | N/A <sup>2</sup>        | N/A <sup>2</sup>                 | 475                    | 18              |

<sup>1</sup> Stocked into the Quality Zone.

<sup>2</sup> Fish that were stocked into the Quality Zone were grouped with fish stocked at the standard stocking locations for survival analysis.

Table 7. Total area of habitat units on the Hiwassee River, Tennessee. ID represents the sequential order of habitat units beginning at Apalachia Powerhouse. Areas were calculated using Geographical Information Systems software.

| Unit Type  | ID  | Area (km <sup>2</sup> ) | Unit Type | ID  | Area (km <sup>2</sup> ) | Unit Type | ID  | Area (km <sup>2</sup> ) | Unit Type | ID  | Area (km <sup>2</sup> ) |
|------------|-----|-------------------------|-----------|-----|-------------------------|-----------|-----|-------------------------|-----------|-----|-------------------------|
| Riffle     | 1   | 0.0157                  | Run       | 3   | 0.0500                  | Pool      | 5   | 0.0625                  | Shoal     | 2   | 0.0140                  |
|            | 4   | 0.0010                  |           | 27* | 0.0059                  |           | 7   | 0.0077                  |           | 6   | 0.0408                  |
|            | 9   | 0.0083                  |           | 29* | 0.0020                  |           | 10  | 0.0429                  |           | 8   | 0.0185                  |
|            | 26* | 0.0005                  |           | 34* | 0.0079                  |           | 12  | 0.0099                  |           | 11  | 0.0155                  |
|            | 28* | 0.0012                  |           | 41* | 0.0022                  |           | 14  | 0.0096                  |           | 13  | 0.0094                  |
|            | 35* | 0.0041                  |           | 44* | 0.0064                  |           | 16  | 0.0151                  |           | 15  | 0.1166                  |
|            | 43* | 0.0023                  |           | 47* | 0.0036                  |           | 17* | 0.0550                  |           | 18* | 0.1968                  |
|            | 48* | 0.0021                  |           | 49* | 0.0079                  |           | 19* | 0.0291                  |           | 20* | 0.0137                  |
|            | 63  | 0.0013                  |           | 52  | 0.0077                  |           | 21* | 0.0130                  |           | 22* | 0.0344                  |
|            | 65  | 0.0127                  |           | 54  | 0.0258                  |           | 23* | 0.0276                  |           | 24* | 0.0426                  |
|            | 68  | 0.0112                  |           | 57  | 0.0371                  |           | 25* | 0.0787                  |           | 30* | 0.0314                  |
|            | 71  | 0.0153                  |           | 66  | 0.0212                  |           | 31* | 0.0321                  |           | 32* | 0.0292                  |
|            | 74  | 0.0051                  |           | 69  | 0.0110                  |           | 33* | 0.1939                  |           | 36* | 0.0366                  |
|            | 81  | 0.0011                  |           | 72  | 0.0085                  |           | 37* | 0.0078                  |           | 38* | 0.0032                  |
|            | 83  | 0.0024                  |           | 79  | 0.0160                  |           | 46* | 0.0701                  |           | 39* | 0.0022                  |
|            | 88  | 0.0090                  |           | 80  | 0.0032                  |           | 50* | 0.0131                  |           | 40* | 0.0642                  |
|            | 90  | 0.0138                  |           | 84  | 0.0141                  |           | 53  | 0.0119                  |           | 42* | 0.0255                  |
|            | 94  | 0.0064                  |           | 91  | 0.0168                  |           | 55  | 0.0082                  |           | 45* | 0.0052                  |
|            | 96  | 0.0013                  |           | 93  | 0.0067                  |           | 58  | 0.0119                  |           | 51  | 0.0471                  |
|            | 99  | 0.0037                  |           | 95  | 0.0107                  |           | 60  | 0.0120                  |           | 56  | 0.0626                  |
|            | 103 | 0.0021                  |           | 97  | 0.0088                  |           | 62  | 0.0160                  |           | 59  | 0.0053                  |
|            | 109 | 0.0021                  |           | 101 | 0.0667                  |           | 73  | 0.0058                  |           | 61  | 0.1604                  |
|            | 111 | 0.0045                  |           | 104 | 0.0170                  |           | 75  | 0.0154                  |           | 64  | 0.0390                  |
|            | 112 | 0.0020                  |           | 106 | 0.0122                  |           | 77  | 0.0398                  |           | 67  | 0.0315                  |
|            | 114 | 0.0005                  |           | 108 | 0.0275                  |           | 82  | 0.0635                  |           | 70  | 0.0045                  |
|            | 116 | 0.0009                  |           | 110 | 0.0306                  |           | 87  | 0.0585                  |           | 76  | 0.0141                  |
|            | 119 | 0.0002                  |           | 113 | 0.0013                  |           | 89  | 0.0490                  |           | 78  | 0.0041                  |
|            |     |                         |           | 115 | 0.0409                  |           | 92  | 0.0815                  |           | 85  | 0.0077                  |
|            |     |                         |           | 117 | 0.1916                  |           | 98  | 0.0391                  |           | 86  | 0.0038                  |
|            |     |                         |           |     |                         |           | 100 | 0.0402                  |           |     |                         |
|            |     |                         |           |     |                         |           | 102 | 0.0164                  |           |     |                         |
|            |     |                         |           |     |                         |           | 105 | 0.0286                  |           |     |                         |
|            |     |                         |           |     |                         |           | 107 | 0.0243                  |           |     |                         |
|            |     |                         |           |     |                         |           | 118 | 0.0113                  |           |     |                         |
| Total Area |     | 0.1308                  |           |     | 0.6613                  |           |     | 1.2015                  |           |     | 1.0799                  |

\* Habitat units within the Quality Zone.

Table 8. Ranges of water quality parameters measured during January 2000 at three sites from the South Fork of the Holston River, Watauga River, Clinch River and Hiwassee River.

| Parameter                            | River        |             |             |             |
|--------------------------------------|--------------|-------------|-------------|-------------|
|                                      | S.F. Holston | Watauga     | Clinch      | Hiwassee    |
| Date Measured                        | 1-15-00      | 1-15-00     | 1-15-00     | 1-20-00     |
| Alkalinity (mg/L CaCO <sub>3</sub> ) | 94 – 110     | 32 – 43     | 110 – 120   | 9 – 12      |
| Conductivity (µS/cm)                 | 233 – 272    | 113 – 145   | 295 – 319   | 41 – 47     |
| Dissolved Oxygen (mg/L)              | 10.2 – 13.0  | 12.7 – 13.3 | 11.0 – 12.3 | 11.2 – 12.9 |
| pH                                   | 7.9 – 8.2    | 7.6 – 7.9   | 8.2 – 8.3   | 7.4 – 7.5   |

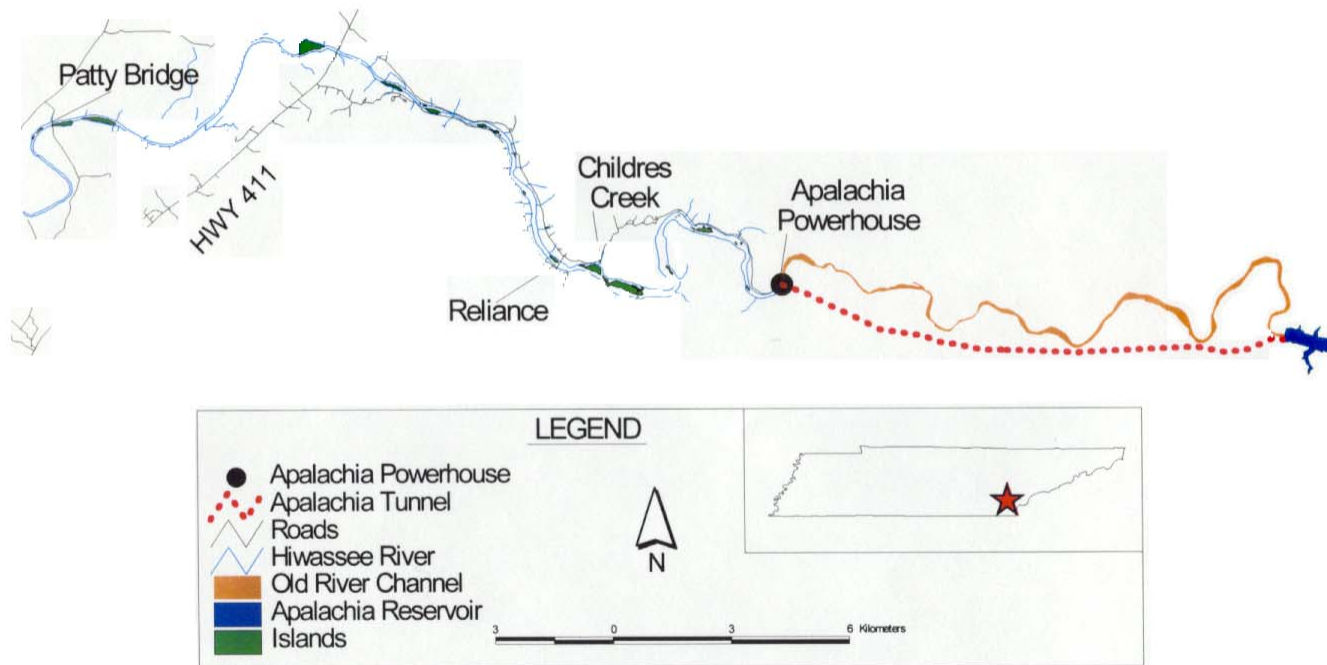


Figure 1. The Hiwassee River tailwater below Apalachia Dam, Tennessee.



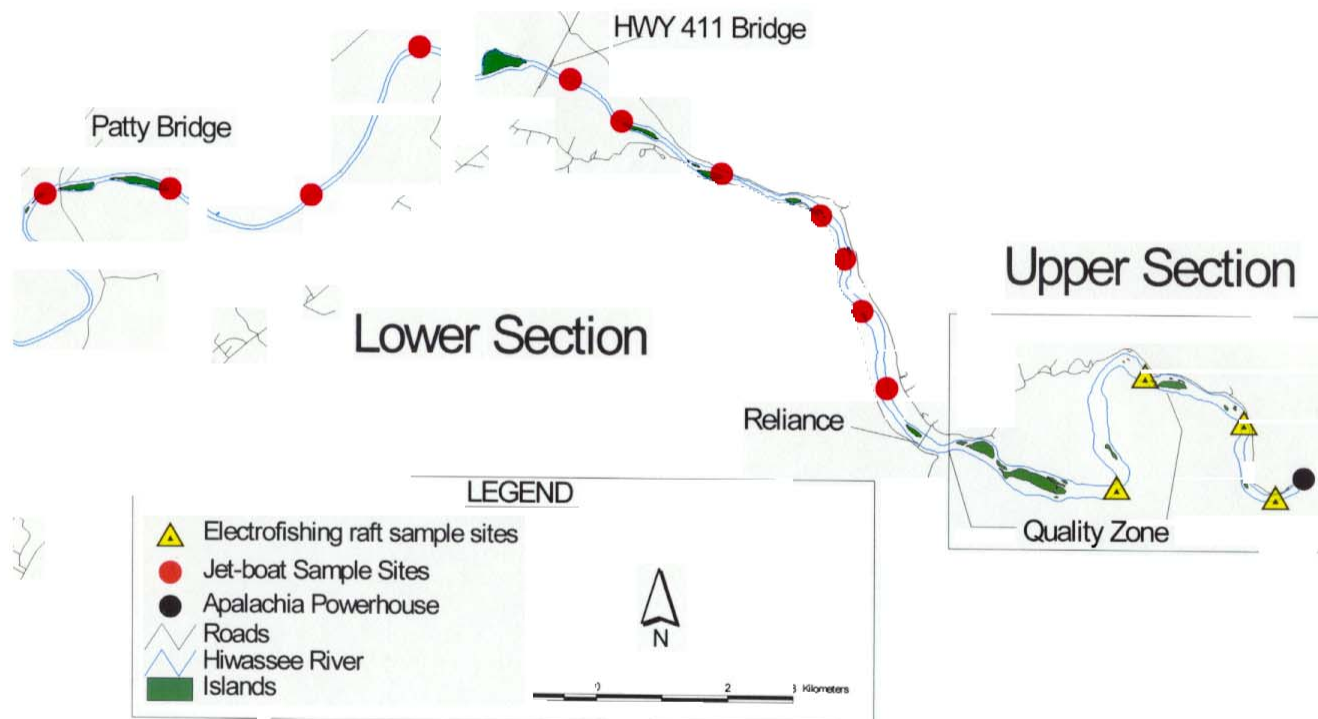


Figure 2. Sample transects on the Hiwassee River tailwater below Apalachia Powerhouse.

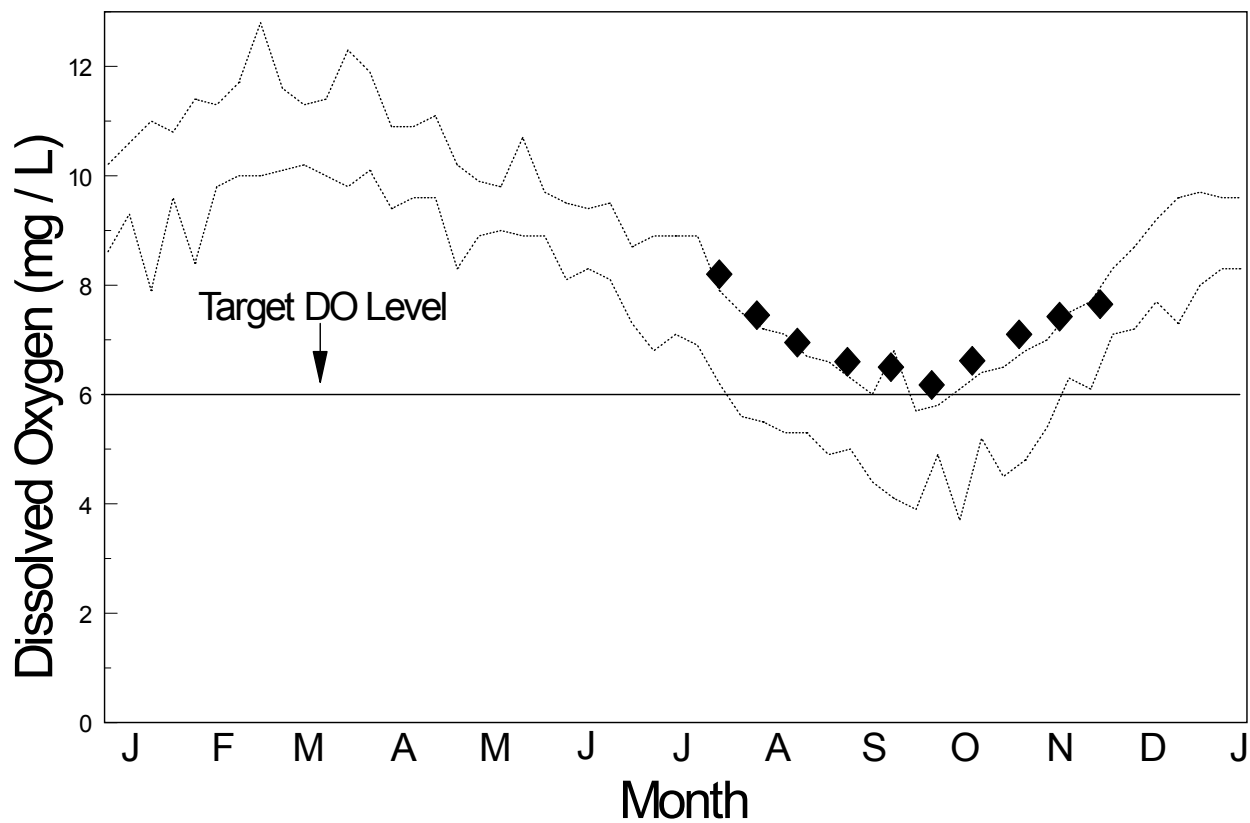


Figure 3. Dissolved oxygen concentrations in the Hiwassee River below Apalachia Powerhouse. Dashed lines represent historic concentrations (10th and 90th percentile) and the diamonds represent data collected from the Apalachia Powerhouse during 1999 (TVA, unpublished data).

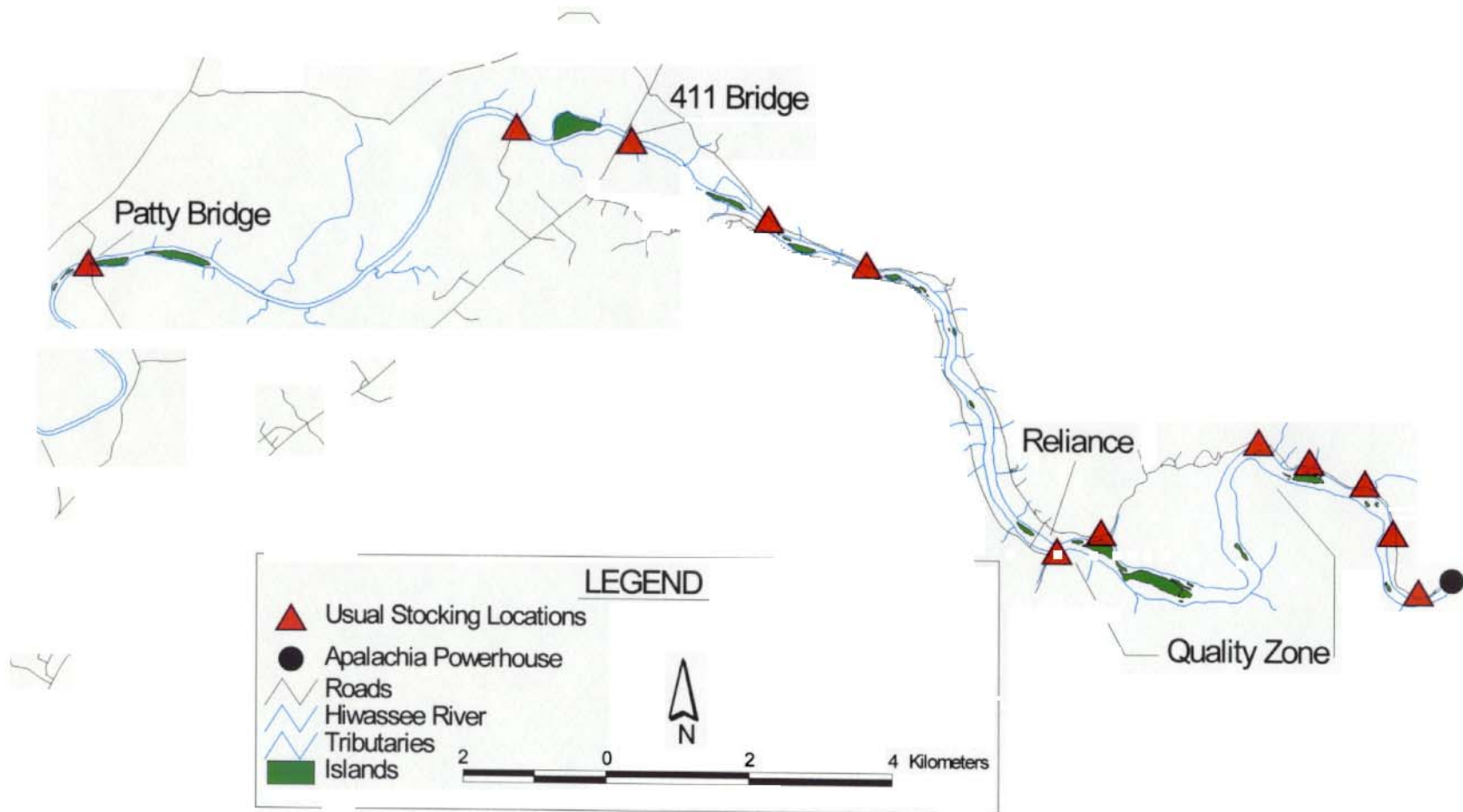


Figure 4. Standard TWRA stocking locations for brown trout and rainbow trout released into the Hiwassee River tailwater below Apalachia Dam during 1999.

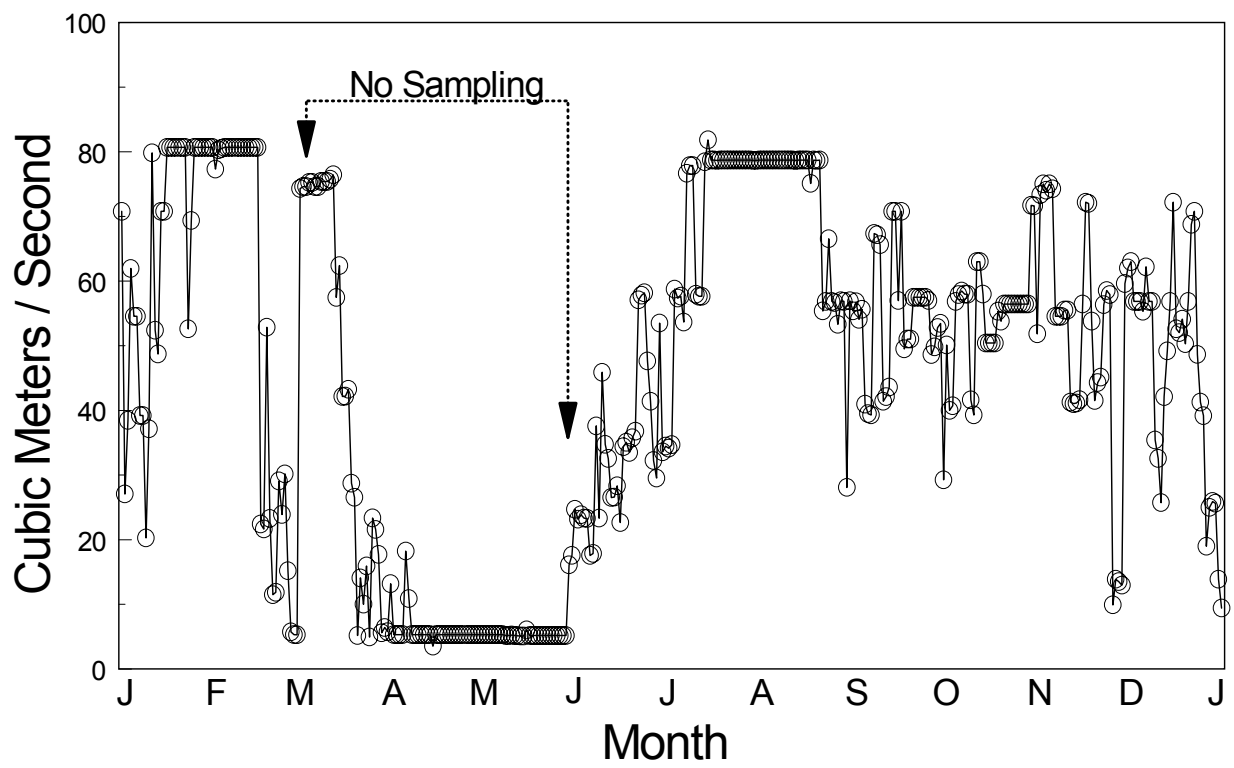


Figure 5. Average daily discharge from Apalachia Powerhouse during 1999. Electrofishing samples were not conducted between 3 March and 6 June 1999 due to low water levels.

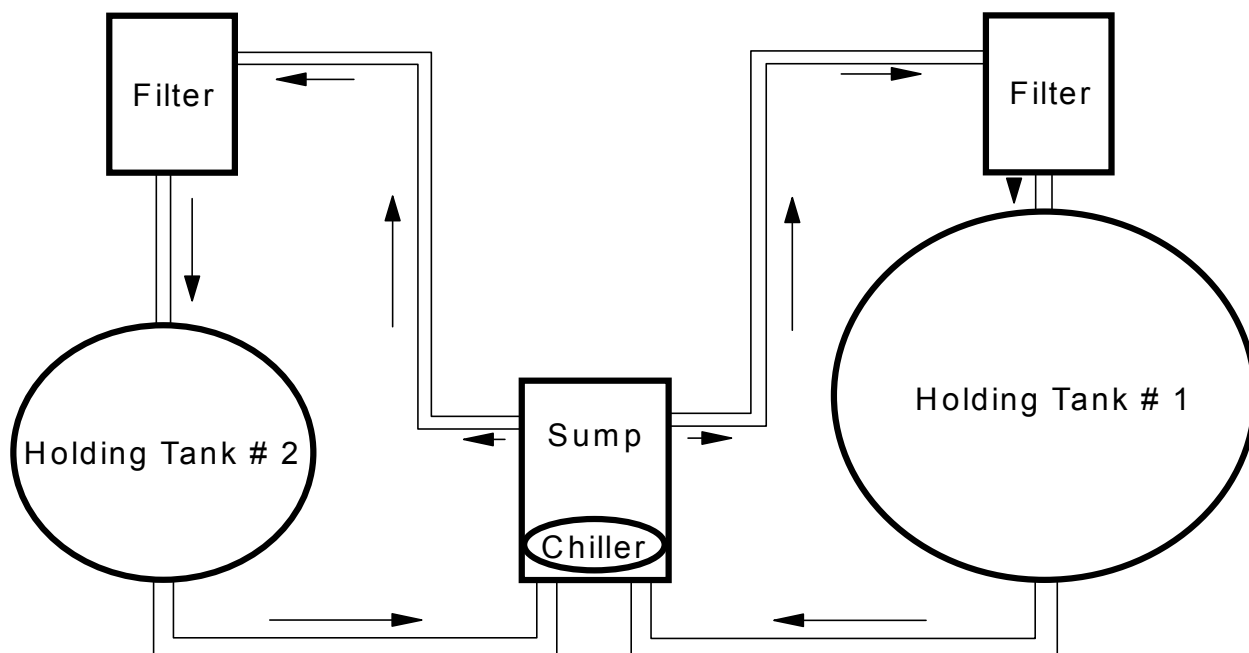


Figure 6. Recirculating system for holding rainbow trout used in temperature study.

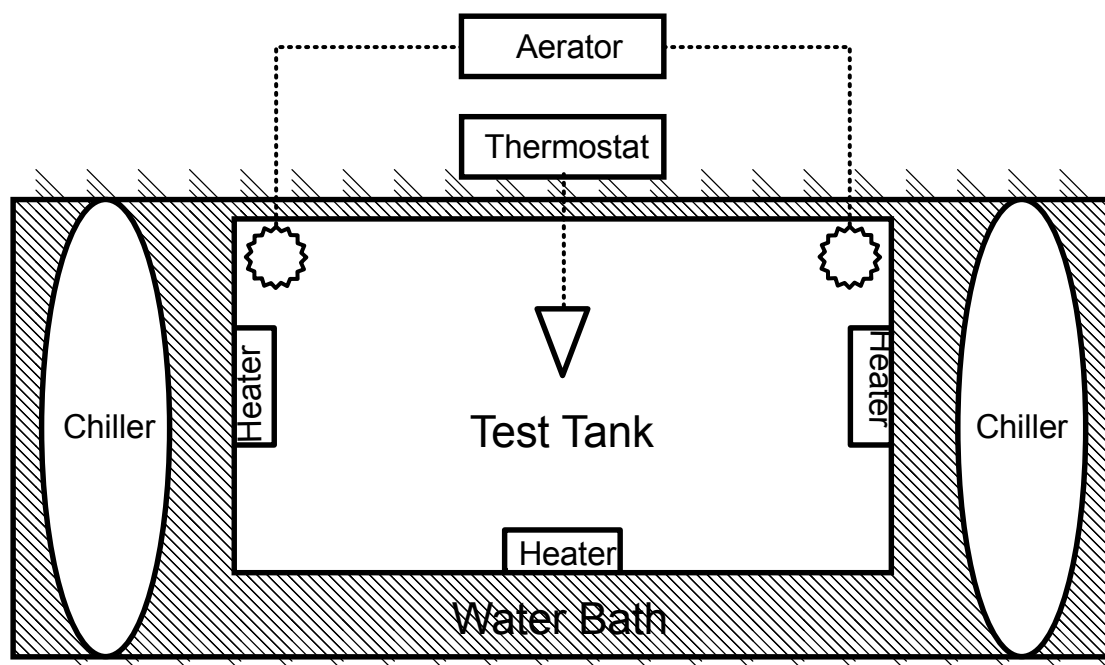


Figure 7. Top view of testing apparatus used in trout temperature study.

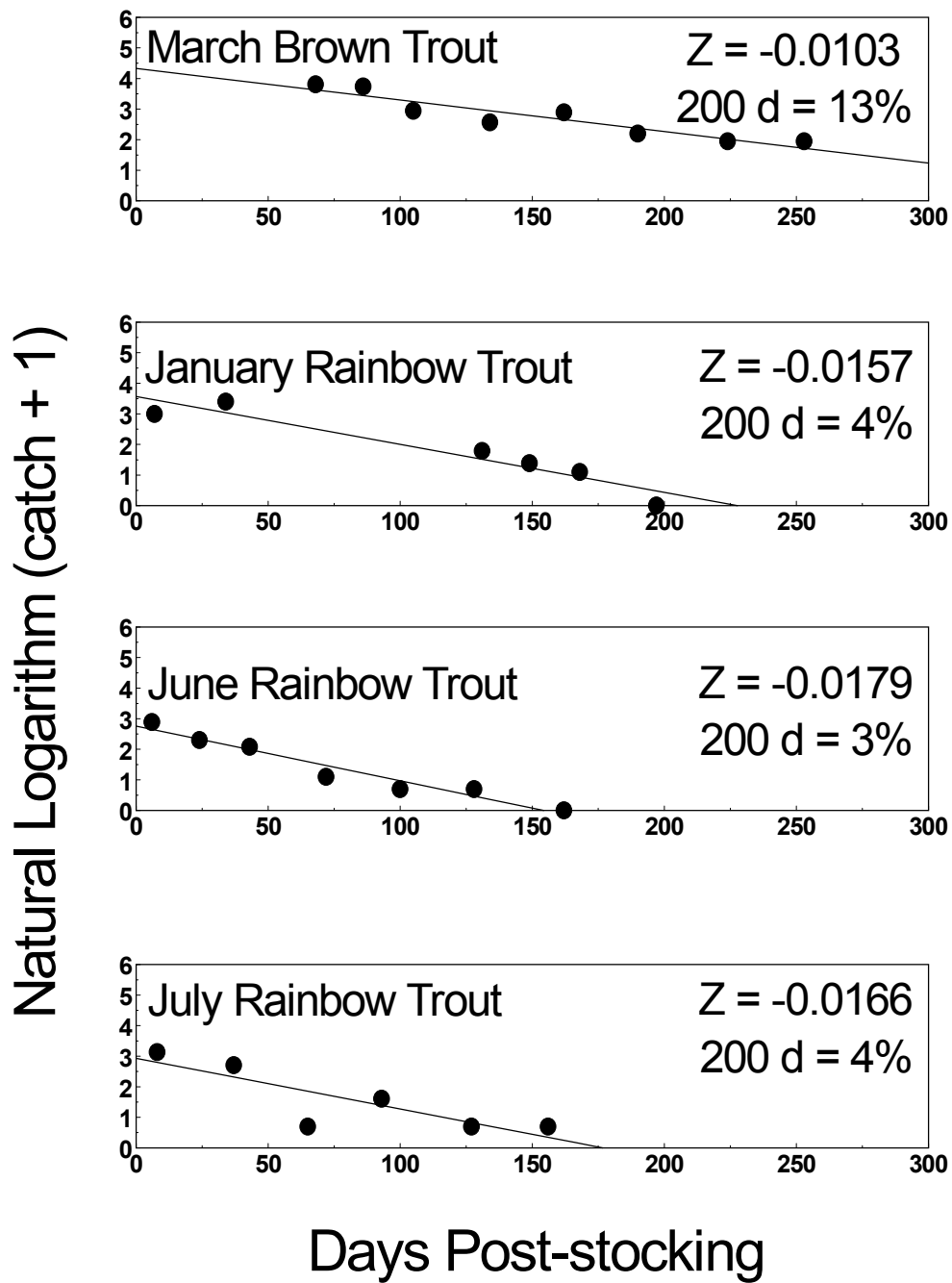


Figure 8. Catch curve analysis for cohorts of microtagged brown trout and rainbow trout stocked into the Hiwassee River below Apalachia Powerhouse in 1999. Instantaneous mortality rates ( $Z$ ) and 200-day survival rates ( $S$ ) are listed.

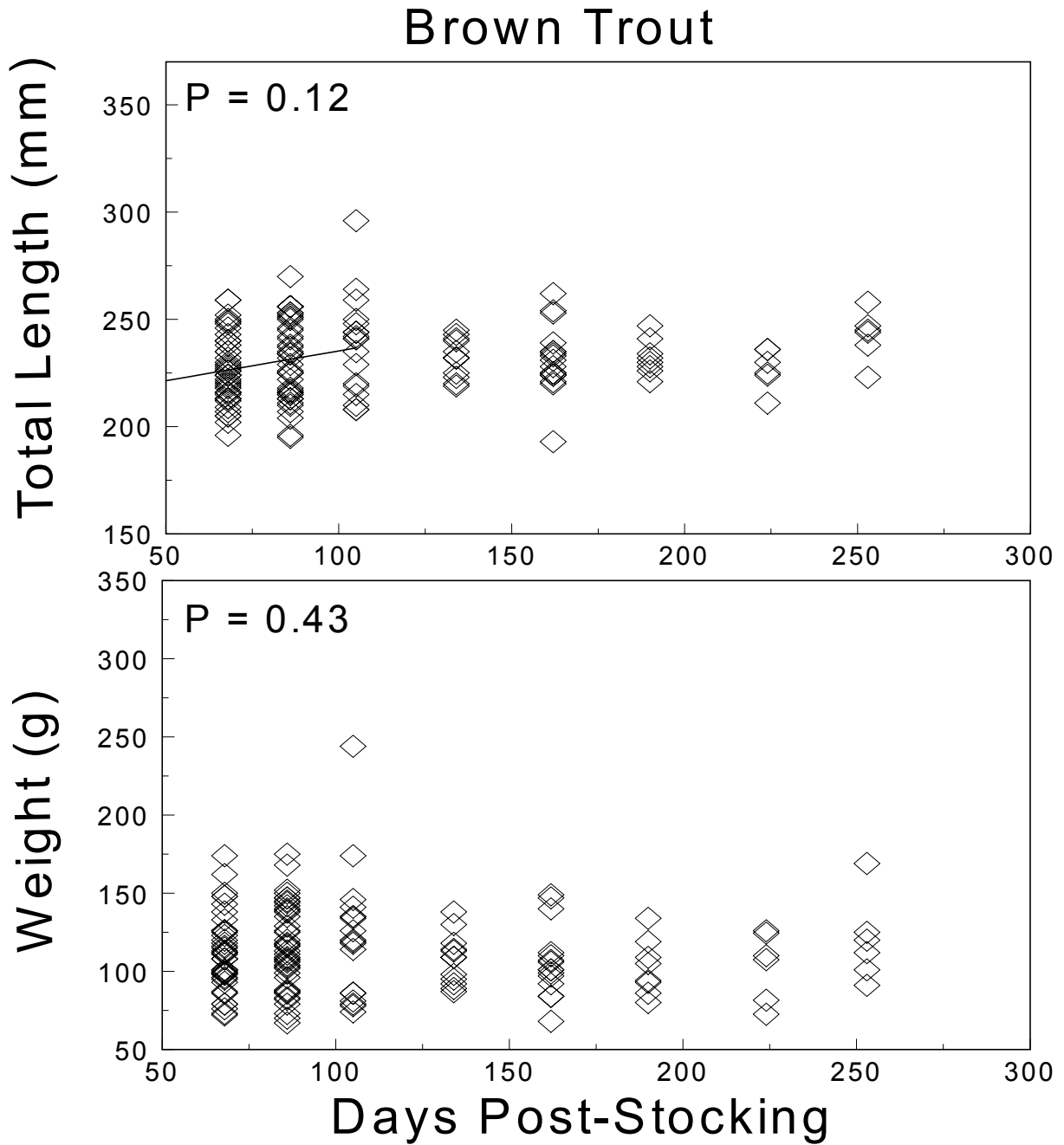


Figure 9. Individual total lengths and weights regressed against days post-stocking for brown trout stocked in March 1999. Significant growth in length was detected only during the first 105 days post-stocking ( $TL = 207 + 0.28 \text{ Day}$ ;  $P = 0.04$ ).

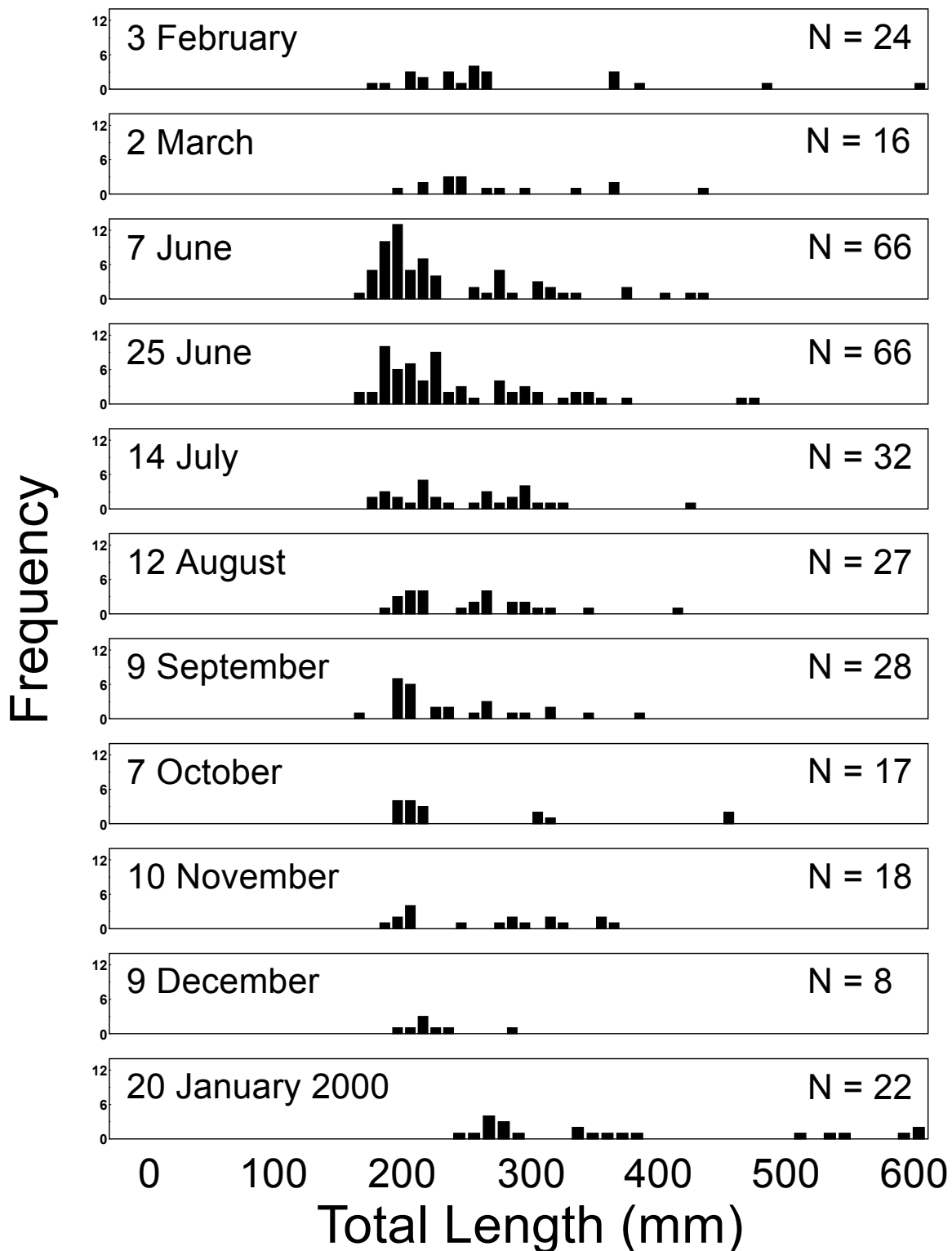


Figure 10. Length-frequencies of all brown trout collected in electrofishing samples from the Hiwassee River in 1999 and January 2000. Brown trout (n = 16,679) were stocked 31 March 1999.



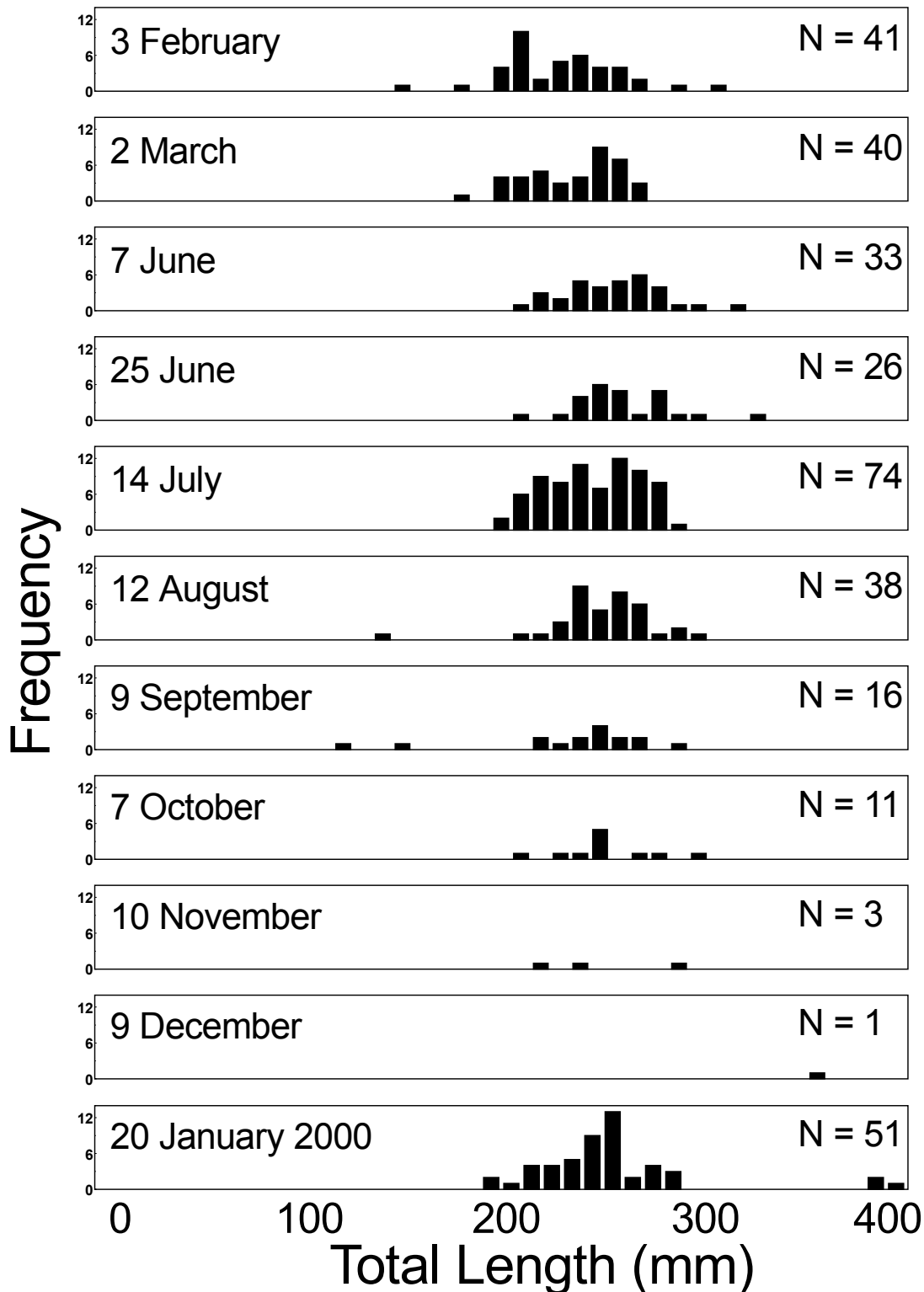


Figure 11. Length-frequencies of all rainbow trout collected in electrofishing samples from the Hiwassee River in 1999 and January 2000. In 1999, rainbow trout were stocked between 14 January and 22 July; in 2000, the first fish were stocked 16 January.

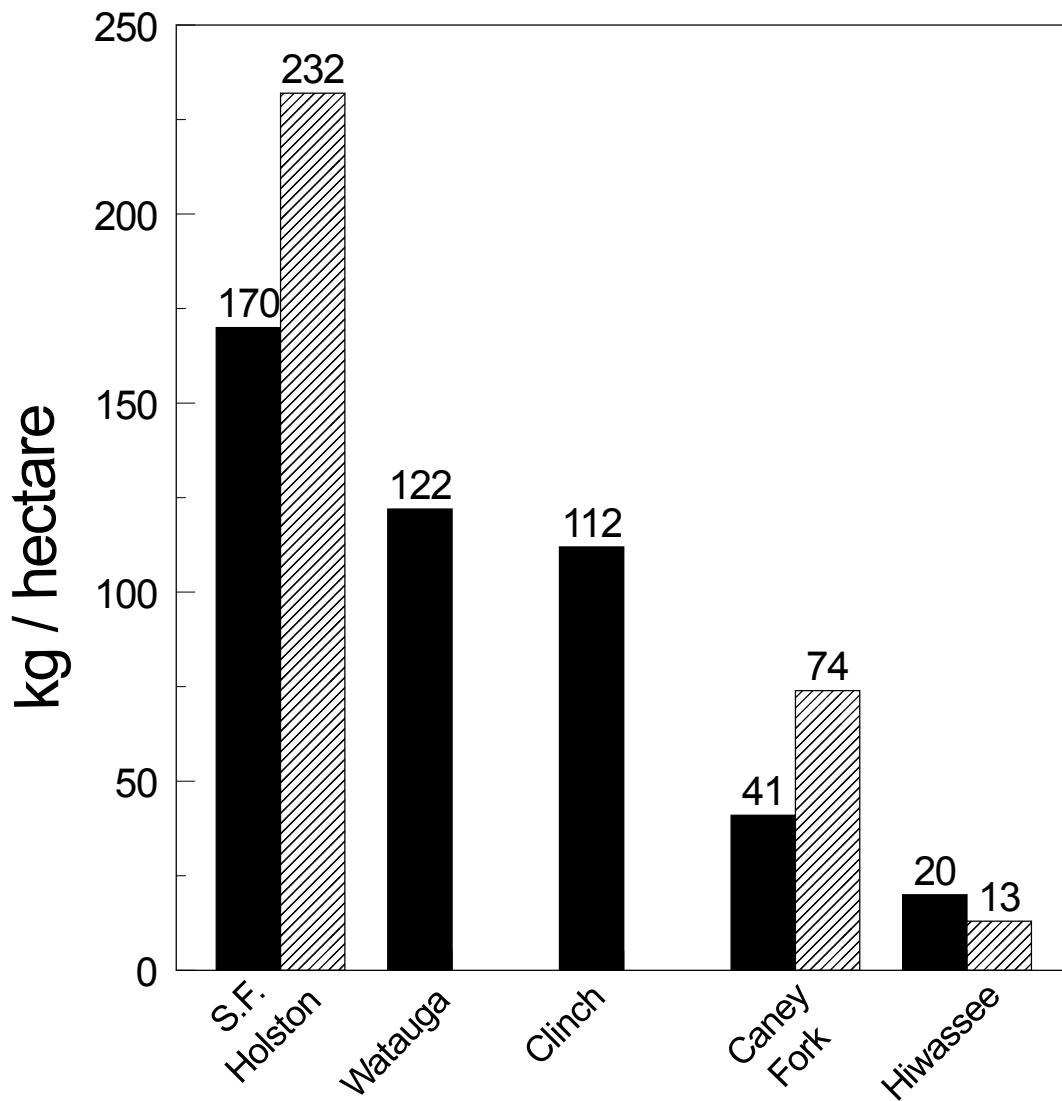


Figure 12. A comparison of trout standing crops in five Tennessee rivers. Multiple estimates (S.F Holston, Caney Fork and Hiwassee) indicate consecutive yearly estimates.

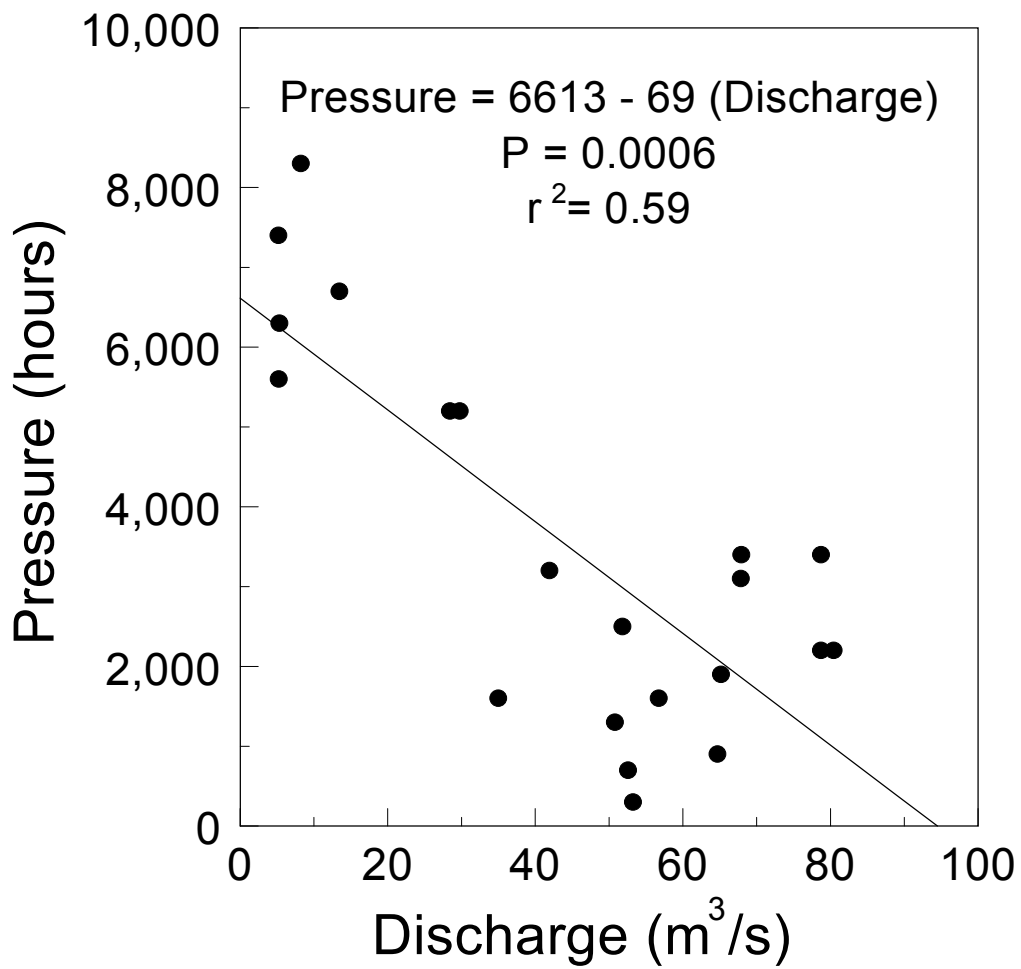


Figure 13. Relationship between average daily discharge and fishing pressure during two-week creel survey periods in 1999 in the Hiwassee River.

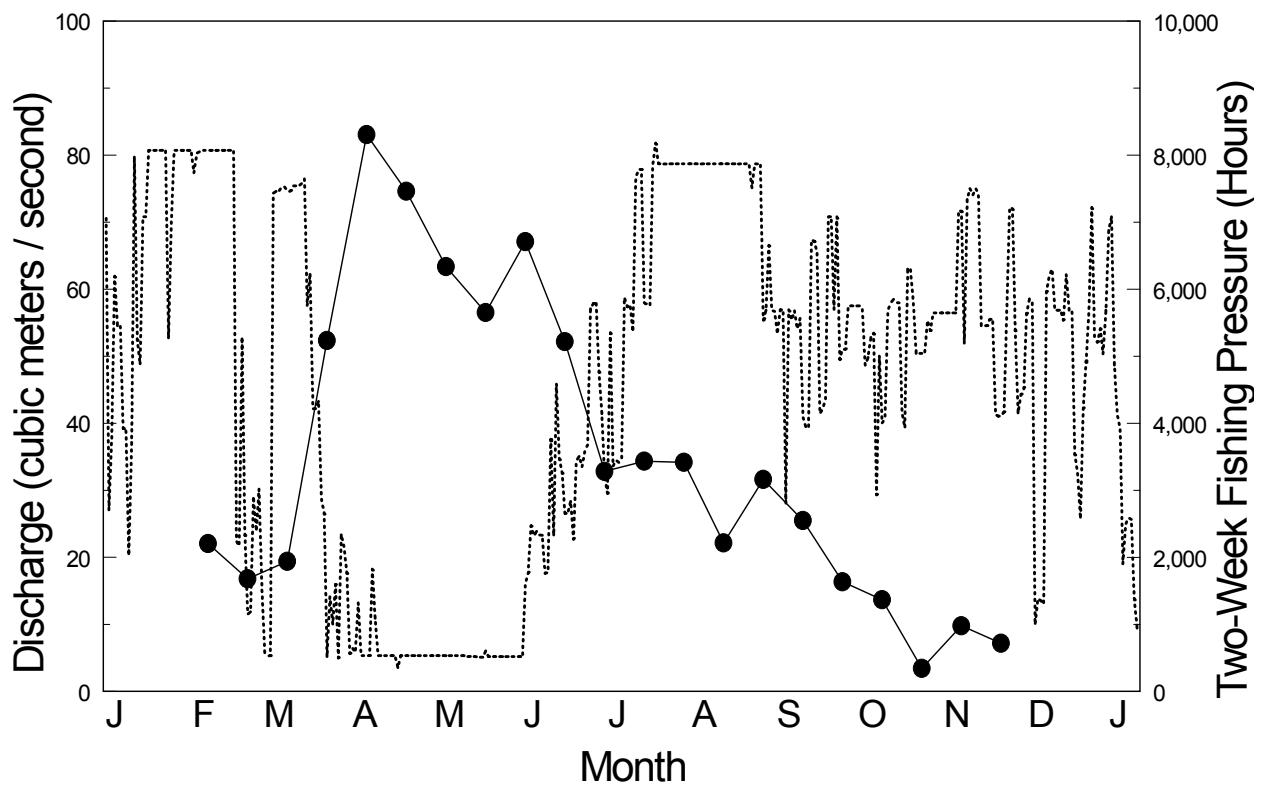


Figure 14. Daily discharge versus fishing pressure on the Hiwassee River below Apalachia Powerhouse during 1999. Dashed line represents mean daily discharge and circles represent total fishing pressure for each of the two-week creel survey periods.

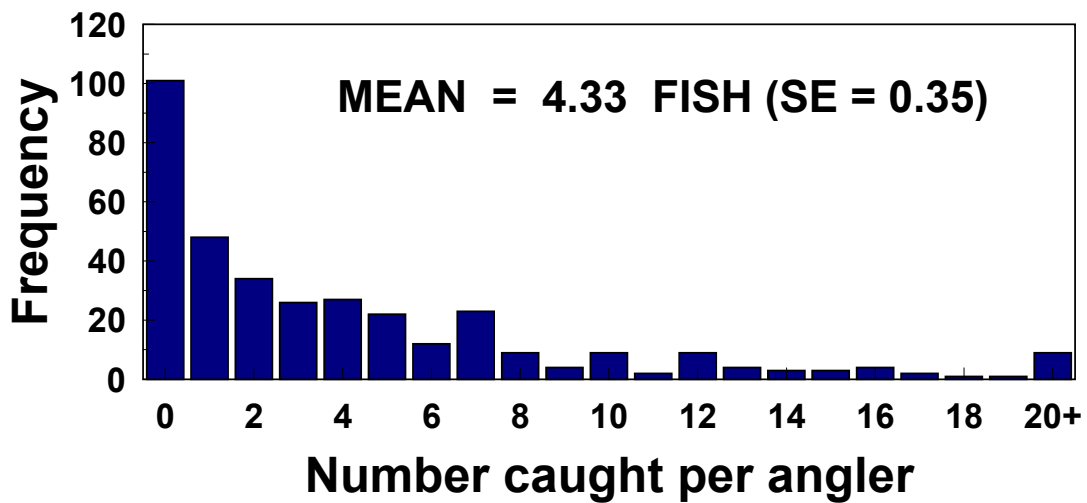
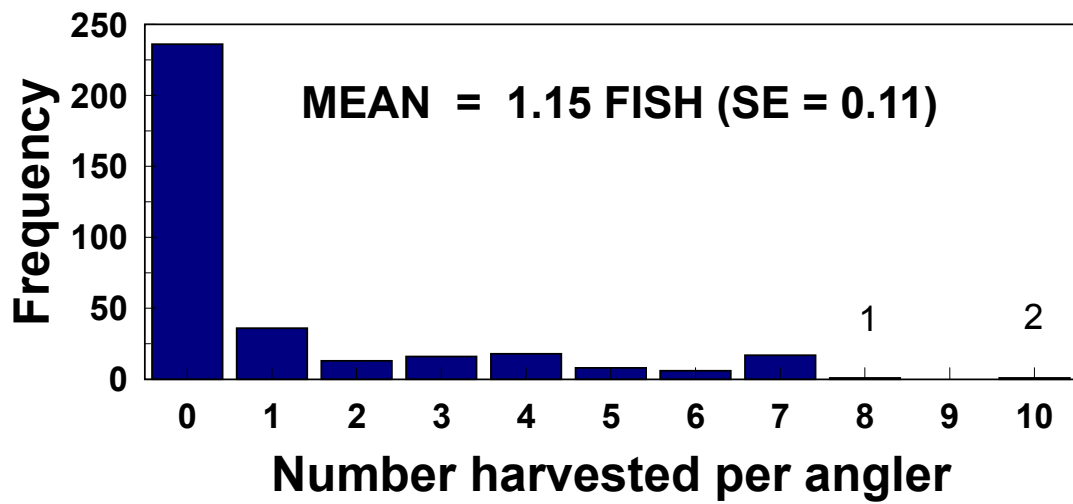
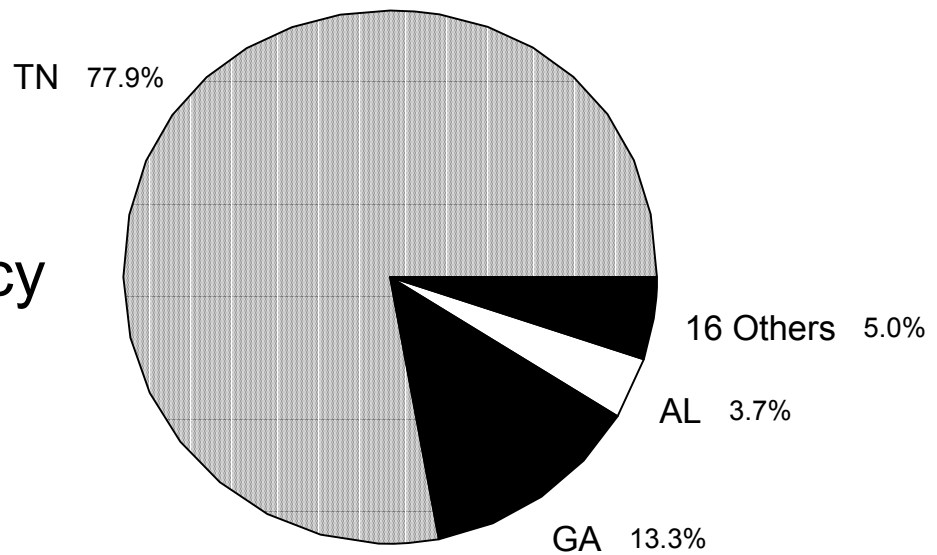


Figure 15. Frequency distribution for the average number of trout harvested and caught by each member of parties that had completed fishing when interviewed on the Hiwassee River, January 1999-November 1999. N = 353 parties.

## State Residency



## County Residency (TN anglers)

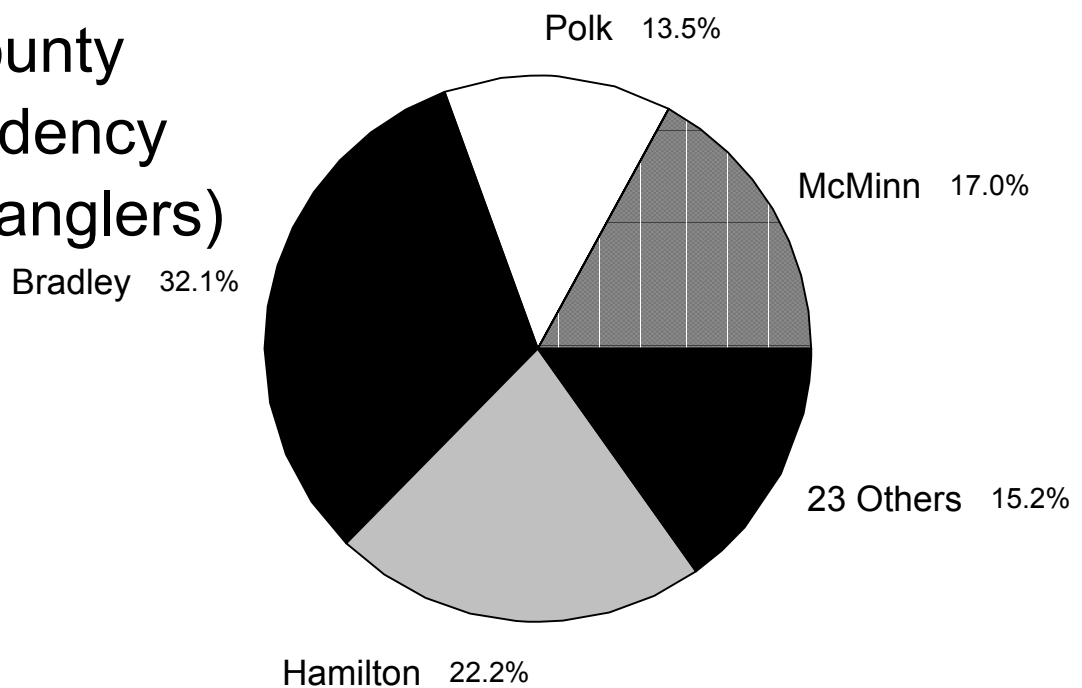


Figure 16. State and county residency of all anglers ( $n = 1,844$ ) and Tennessee anglers ( $n = 1,347$ ) interviewed on the Hiwassee River, January -November 1999.

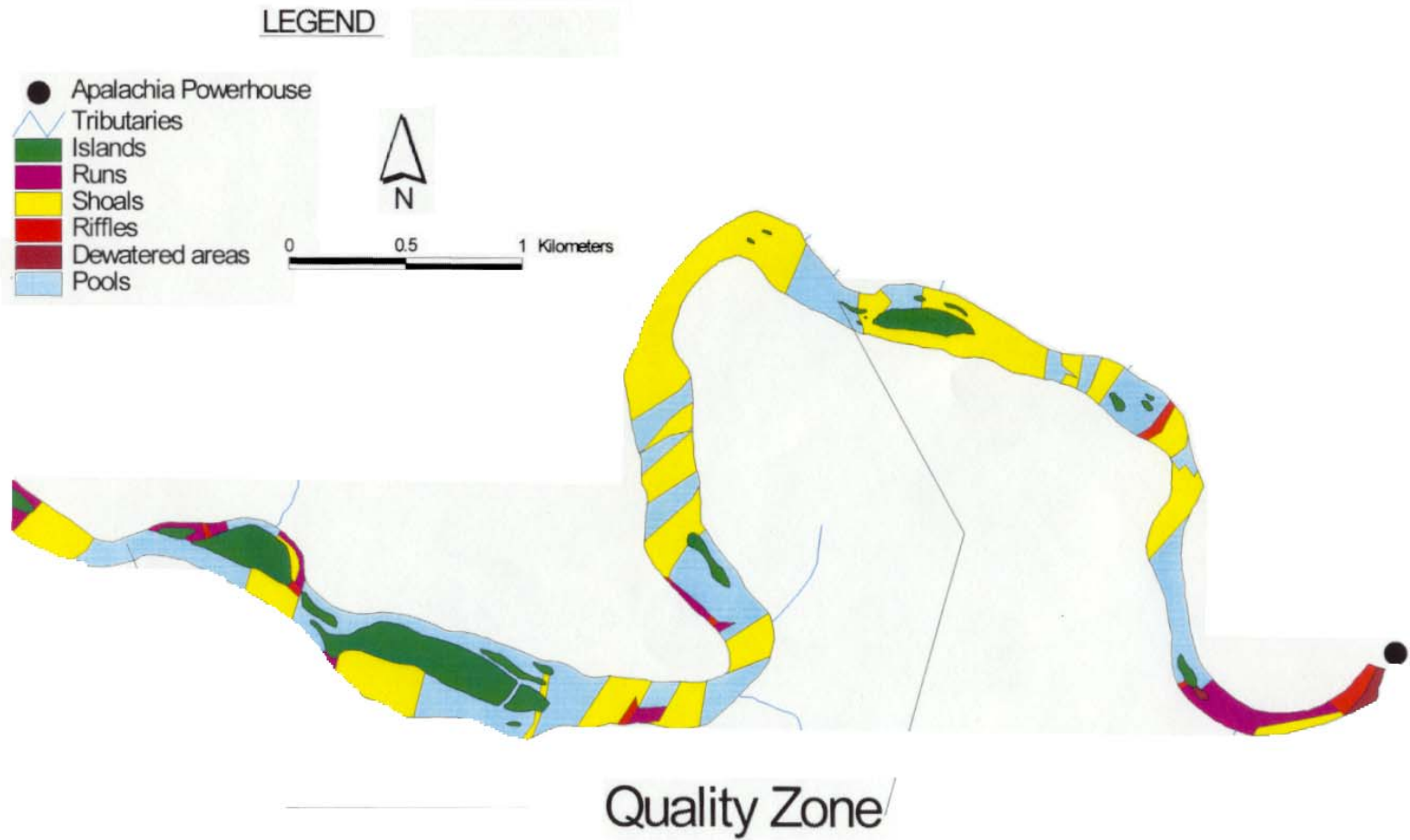


Figure 17. Habitat in the upper section of the Hiwassee River below Apalachia Powerhouse. Dewatered areas were completely dry during periods of generation.

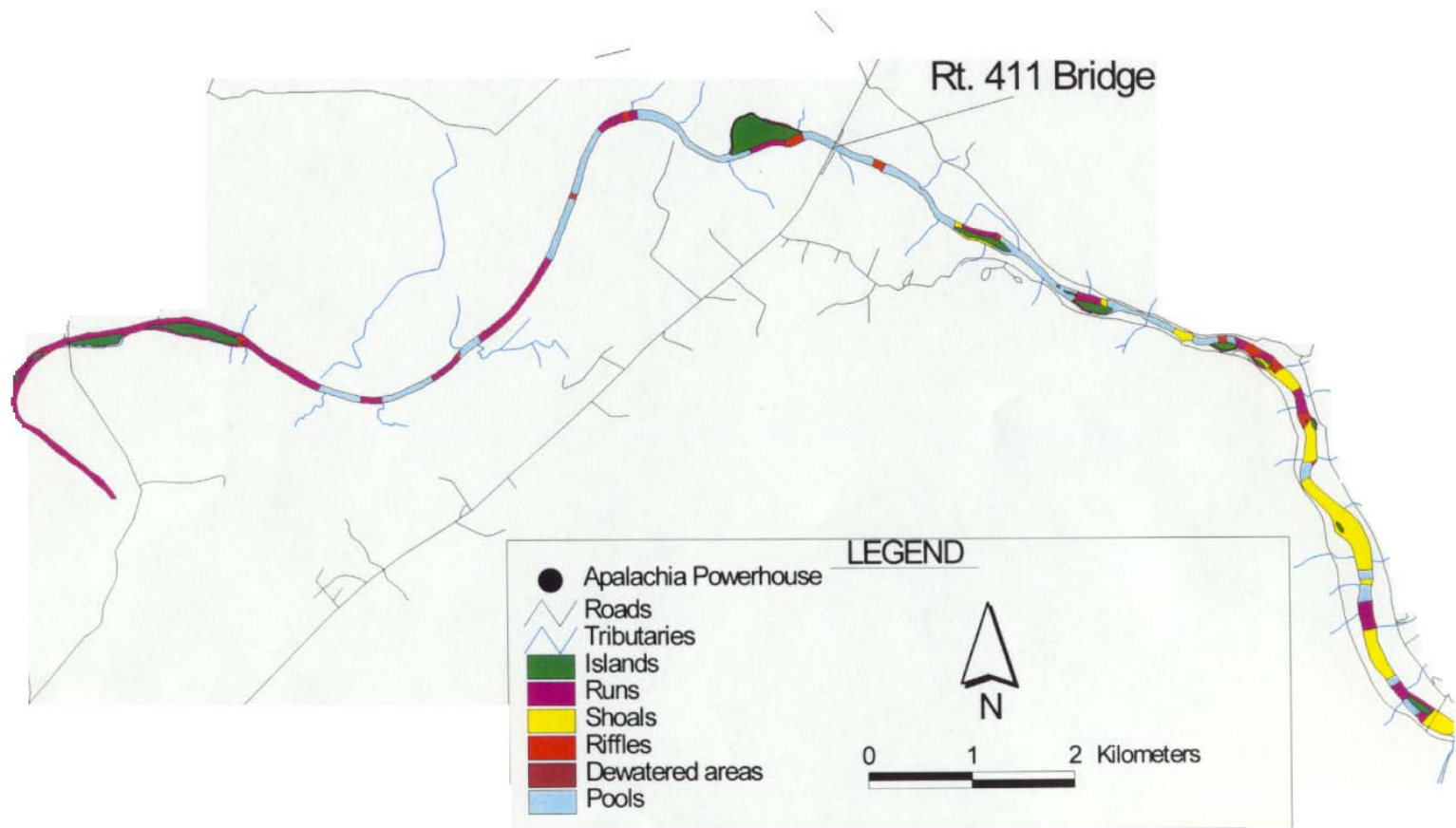


Figure 18. Habitat in the lower section of the Hiwassee River below Apalachia Powerhouse. Dewatered areas were completely dry during periods of generation



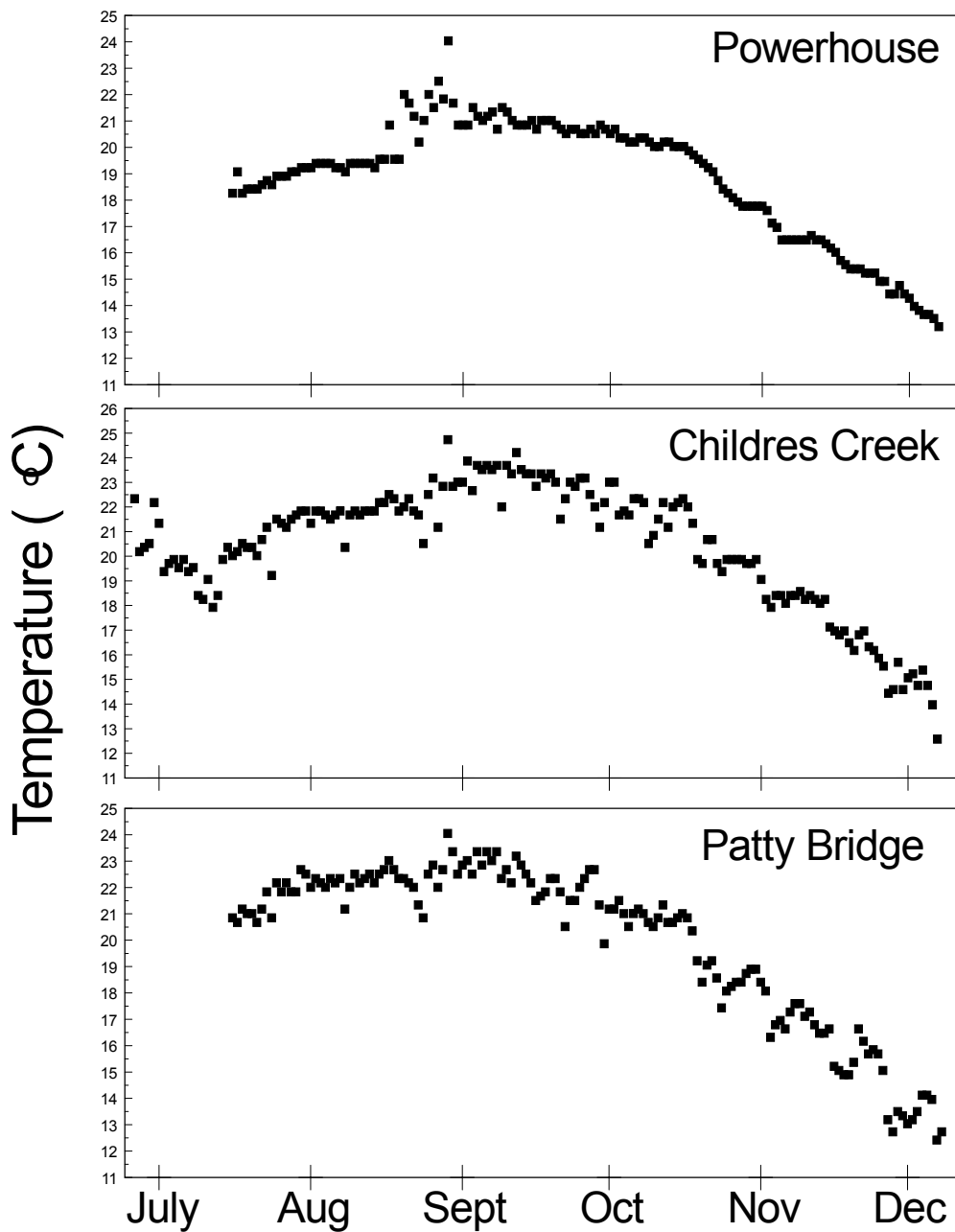


Figure 19. Maximum daily temperatures recorded on the Hiwassee River from July through December 1999. For river locations see Figure 1.

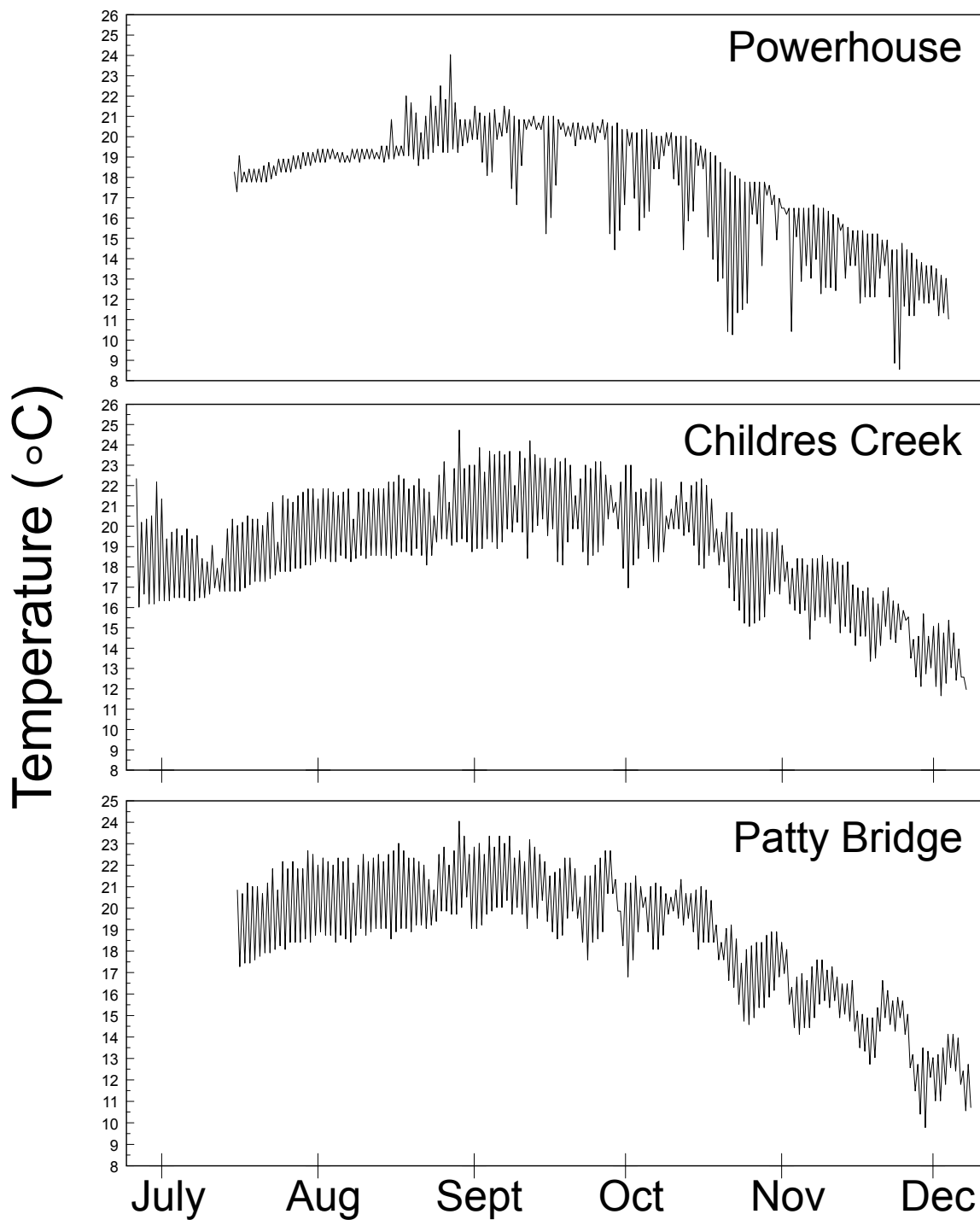


Figure 20. Daily minimum and maximum water temperatures recorded on the Hiwassee River from July through December 1999. For river locations see Figure 1.

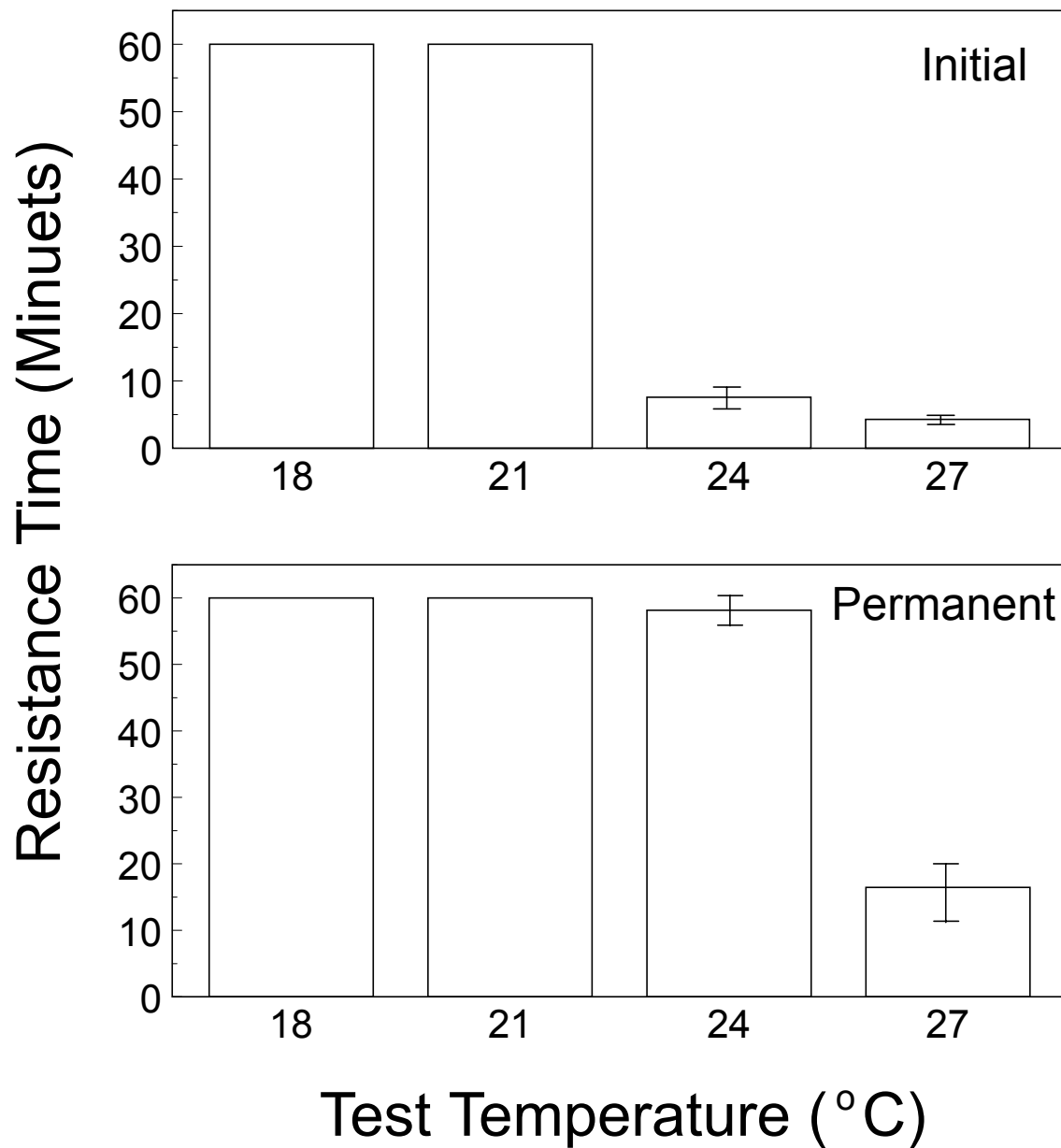


Figure 21. Mean resistance times (and standard errors) to initial and permanent equilibrium loss for rainbow trout acclimated to 10°C. For each test temperature,  $n = 8$ . Each trial lasted 60 minutes.

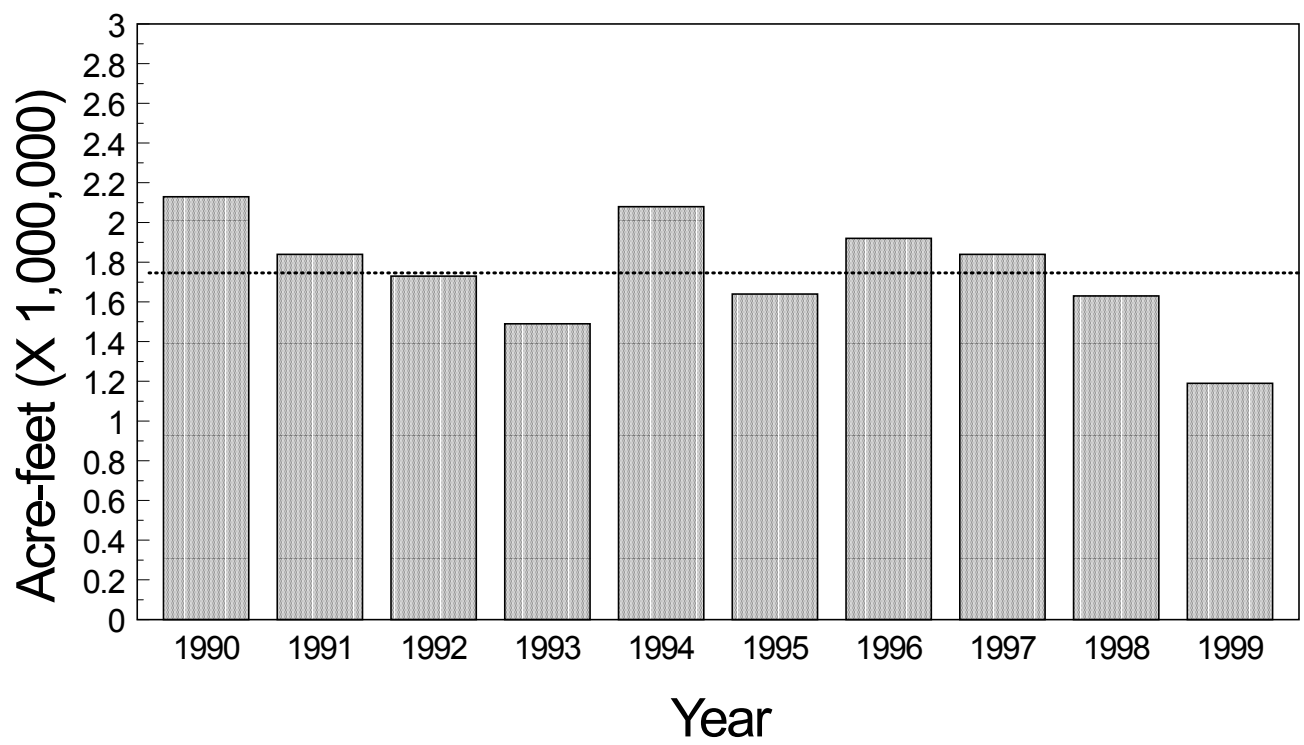


Figure 22. Total amount of water released annually through Apalachia Dam, 1990 - 1999.  
Dashed line indicates the 10-year average.

## **APPENDIX**

### **Creel survey Forms**

## DAILY SAMPLE SHEET - HIWASSEE 1999

DATE (mo/day/year) \_\_\_\_\_ 2-WEEK PERIOD \_\_\_\_\_  
(1-21)

KIND OF DAY \_\_\_\_\_  
(01 = weekday 02= weekend)

AREA ( 1 OR 2) \_\_\_\_\_ SHIFT (AM or PM) \_\_\_\_\_

PROBABILITY \_\_\_\_\_

TIME COUNT BEGAN \_\_\_\_\_  
(military time)

RIVER STAGE IN WORK AREA \_\_\_\_\_  
WHEN COUNT BEGAN (0 = NO GENERATION, 1 = PARTIAL , 2 = FULL)

| <u>RIVER REACH</u> | <u>NUMBER<br/>OF ANGLERS</u> | <u>NUMBER<br/>OF BOATS</u> | <u>NUMBER<br/>OF TRAILERS</u> |
|--------------------|------------------------------|----------------------------|-------------------------------|
|--------------------|------------------------------|----------------------------|-------------------------------|

1. ABOVE QUALITY ZONE

---

2. QUALITY ZONE

---

3. RELIANCE-TO-RT.411

---

4. FROM RT.411-TO-PATTY BRIDGE

---

“Boats” refers to any canoes, drift boats, or jonboats with people fishing.

“Trailers” refers to any trailer used to haul a drift boat or jonboat.

**TOTALS** \_\_\_\_\_

| ANGLERS | BOATS | TRAILERS |
|---------|-------|----------|
|---------|-------|----------|

Number of Anglers per boat \_\_\_\_\_ Clerk \_\_\_\_\_

### INTERVIEW SHEET - HIWASSEE RIVER

DATE (MO/DAY/YEAR) \_\_\_\_\_ INTERVIEW NUMBER \_\_\_\_\_

PERIOD (01 - 21) \_\_\_\_\_ KIND-OF-DAY \_\_\_\_\_  
Weekday = 1 Weekend / holiday = 2

ACCESS POINT (1,2, 3, OR 4) \_\_\_\_\_ NUMBER IN PARTY \_\_\_\_\_

START OF FISHING \_\_\_\_\_ END OF FISHING \_\_\_\_\_  
(MILITARY TIME) (Time of interview) (MILITARY TIME)

Time Fishing \_\_\_\_\_ COMPLETED TRIP? \_\_\_\_\_  
By Party \_\_\_\_\_ YES = 1 NO = 2  
MIN \_\_\_\_\_

SPECIES FISHED FOR: CHECK ONE TROUT \_\_\_\_\_ OTHER or ANY \_\_\_\_\_  
(1) (2)

NUMBER OF RAINBOWS CAUGHT = \_\_\_\_\_

NUMBER OF RAINBOWS KEPT : UNTAGGED \_\_\_\_\_ DORSAL (D) \_\_\_\_\_  
CAUDAL(C) \_\_\_\_\_ ANAL (A) \_\_\_\_\_ LEFT PECTORAL (LP) \_\_\_\_\_ SNOUT (S) \_\_\_\_\_

LENGTHS OF TAGGED RAINBOWS ( & TAG LOCATION) \_\_\_\_\_

\_\_\_\_\_

LENGTHS OF ANY UNTAGGED RAINBOWS OVER 35 CM \_\_\_\_\_

NUMBER OF BROWNS CAUGHT = \_\_\_\_\_

NUMBER OF BROWNS KEPT : Untagged \_\_\_\_\_ Tagged(Dorsal) \_\_\_\_\_ Tagged (Caudal) \_\_\_\_\_

LENGTHS OF TAGGED BROWNS (& tag location) \_\_\_\_\_

\_\_\_\_\_

LENGTHS OF ANY UNTAGGED BROWNS OVER 35 CM \_\_\_\_\_

For METHOD, TERMINAL GEAR, and LOCATION, the numbers entered should equal the number in the party.

METHOD: STILLFISHING \_\_\_\_\_ SPINFISHING \_\_\_\_\_ FLYFISHING \_\_\_\_\_

TERMINAL GEAR ARTIFICIAL LURES or FLIES \_\_\_\_\_ BAIT \_\_\_\_\_

LOCATION: ON BANK/WADING \_\_\_\_\_ IN BOAT \_\_\_\_\_ FLOAT-TUBE \_\_\_\_\_

STATE \_\_\_\_\_ AND COUNTY(IF TENN) \_\_\_\_\_ OF RESIDENCE

RAINBOW: JAN (D); MAR ( C ); JUN (LP); JUNE-QZ ( A ) ; JULY (S) BROWNS: QZ ( C ); OTHERS ( D )